2005-09

The Forward Observer Personal Computer Simulator (FOPCSim) 2

Strom, Mark W.; McDonough, James

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/1970

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE FORWARD OBSERVER PERSONAL COMPUTER SIMULATOR (FOPCSIM) 2

by

James McDonough
Mark Strom

September 2005

Thesis Advisor: Rudy Darken
Second Reader: Erik Johnson

This thesis done in cooperation with the MOVES Institute.
Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** September 2005	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE: The Forward Observer Personal Computer Simulator (FOPCSim) 2			**5. FUNDING NUMBERS**
6. AUTHOR(S) James McDonough and Mark Strom			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

Due to declining budgets and decreases in ammunition allowances, the opportunity to conduct live fire artillery training has been greatly reduced. The available simulation trainers are either outdated, require specialize contractor support, or are not deployable. FOPCSim was developed at no cost, is freely available, takes advantages of modern 3D graphics, eliminates costly contractor support, and will run on laptops in support of deploying units. The simulator provides users with real-time performance feedback based on the Marine Corps Training and Readiness standards and was designed according to a cognitive task analysis of the call for fire procedures. To evaluate how well FOPCSim trains the call for fire procedures, an experiment was conducted at The Basic School in Quantico, Virginia. FOPCSim was used in place of the current simulation: Training Set, Fire Observation (TSFO) to evaluate its training effectiveness. By eliminating the overhead associated with most simulators, FOPCSim allows users to perform the call for fire procedures with a high degree of repetitiveness which is needed to train this type of task.

14. SUBJECT TERMS Field Artillery, Forward Observer, Call for Fire, FOPCSim, Training, Virtual Environments, Fire Support, Simulation, Open Source			**15. NUMBER OF PAGES** 123
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

FORWARD OBSERVER PERSONAL COMPUTER SIMULATOR 2

James P. McDonough
Major, United States Marine Corps
B.S, U.S. Naval Academy, 1994

MASTER OF SCIENCE IN MODELING, VIRTUAL ENVIRONMENT, AND SIMULATION (MOVES)

Mark W. Strom
Captain, United States Marine Corps
B.S, U.S. Naval Academy, 1999

MASTER OF SCIENCE IN COMPUTER SCIENCE

Submitted in partial fulfillment of the
requirements for the degree of

from the

NAVAL POSTGRADUATE SCHOOL
September 2005

Author: James P. McDonough

Mark W. Strom

Approved by: Rudolph P. Darken
Thesis Advisor

Rolf Erik Johnson
Second Reader

Rudolph P. Darken
Chair, MOVES Academic Committee

Peter Denning
Chairman, Department of Computer Science

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

Due to declining budgets and decreases in ammunition allowances, the opportunity to conduct live fire artillery training has been greatly reduced. The available simulation trainers are either outdated, require specialize contractor support, or are not deployable. FOPCSim was developed at no cost, is freely available, takes advantages of modern 3D graphics, eliminates costly contractor support, and will run on laptops in support of deploying units. The simulator provides users with real-time performance feedback based on the Marine Corps Training and Readiness standards and was designed according to a cognitive task analysis of the call for fire procedures. To evaluate how well FOPCSim trains the call for fire procedures, an experiment was conducted at The Basic School in Quantico, Virginia. FOPCSim was used in place of the current simulation: Training Set, Fire Observation (TSFO) to evaluate its training effectiveness. By eliminating the overhead associated with most simulators, FOPCSim allows users to perform the call for fire procedures with a high degree of repetitiveness which is needed to train this type of task.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

We would like to take this opportunity to thank several individuals who have made the completion of this thesis possible through their assurance, guidance, and support. We would first like to thank Dr. Rudy Darken for providing the guidance, resources, and encouragement to complete our project. We would also to like thank the following people for providing us their technical expertise and recommendations which contributed to the success of this project: J.P. Jamison, Chris Osborn, Erik Johnson, Matt Pritchard and John Locke. We would also like to thank Dr. Amela Sadagic and Dr. William Becker who provided their professional expertise and encouragement throughout our work.

We would also like to thank LtCol Brannon, Maj Villandre, and Ilias Svarnas for all of their hard work and dedicated effort to create a solid starting point with FOPCSim 1.

Finally, we would like to thank our wives, Kim and Maricela for their support and patience during our time in Monterey. Without their support, the completion of this thesis and earning our Master's Degree would not have happened.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. PROBLEM STATEMENT

The procedure to call for artillery fire is a basic skill that is taught at a different school houses throughout the Marine Corps. All officers and many enlisted are required to retain this knowledge and may be called upon to use this skill in a tactical situation. After initially learning the call for fire skill most Marines rarely have an opportunity to practice the skill and the complex nature of the task makes it very perishable. The schoolhouses utilize different simulators in addition to classroom instruction and live fire to teach the skill to students. Because the call for fire skill is perishable and the only virtual simulators are located at the schoolhouse or Marine Expeditionary Force (MEF) simulation centers, a training void is created at the unit level where no virtual training systems to help maintain the proficiency of the call for fire skill are available. In a previous thesis an attempt was made to create a Forward Observer (FO) trainer that would run on a laptop to fill the training void and solve the problem. A training system was created but it did not address the primary problem which was funding limitations.

The first version of FOPCSim utilized a commercial simulation engine to produce a virtual training environment. Although the graphics were adequate, the runtime license associated with distributing the application was very costly. With the problem now more clearly defined, this thesis attempts to solve the problem by using free software with no licensing fees. By using the internet as a means of distribution, a free training solution to address the problem of training and maintaining the call for fire skill is achieved.

Four goals had to be achieved in order to create a successful training tool. First, the software had to be free for the users. Second, the software must train the proper skills. Third, the software must be modifiable by the end users so they could meet their training requirements. Forth, the system must be able to function as a team trainer.

The solution to the first problem was actually the easiest. The MOVES Institute at the Naval Postgraduate School, Monterey, CA was in the process of developing an open source freely distributable gaming and simulation engine of their own: Delta3D.

This engine offered many advantages that other open-source engines did not have available such as native support for High Level Architecture (HLA) networking, built in sound support, and easy access to the development team. Because the engine had GNU Lesser General Public License, this meant that we would be able to distribute our application to all of our users at no cost. By making the software no cost we could effectively reach our target audience at the unit level and take advantage of the internet to distribute the training system.

Anyone can build an application and call it a training system so it is important, especially in a life or death situation such as combat, that the skills learned when using the training system properly train the user. To ensure that FOPCSim would properly meet the training requirements a thorough cognitive task analysis (CTA) of the call for fire procedure was conducted prior to the system design. The CTA was used as the foundation for the architecture of the system. We felt it was more efficient to design the system based on the training requirement instead of manipulating the training requirement around the system. After the software was created a training effectiveness experiment was then conducted at the Basic Officer Course, The Basic School, Training and Education Command (TECOM), Quantico, VA to validate the effectiveness of the system.

To make the training system as useful as possible and to meet unforeseen uses of the training system we wanted the training scenarios to be modifiable by the users. To solve this problem scenario information was moved out of system code and placed in Extensible Markup Language (XML) files to provide users the ability to adjust or modify the system to meet their needs. HTML tutorials were also created to aid users in the modification process.

Finally, in the initial design we identified how this system could logically fit into a team training scenario. In order for this to happen the system would have to have the ability to interface with a real C4I system called the Advanced Field Artillery Tactical Data System (AFATDS). Fortunately, the company BMH Inc. had already designed this interface that works across an HLA network. Because our engine natively supports HLA networking we are able to seamlessly turn our training system into a team trainer by

allowing the FO to send missions to the Fire Direction Center (FDC) where the data is computed using the actual C4I equipment they use in both training and real world operations.

B. MOTIVATION

Recently due to budget constraints the ability to remain proficient at calling for fire has been greatly reduced, and at the same time the need to be proficient has greatly increased due to the Global War on Terrorism. Live fire ranges have become scarcer as well as the amount of practice ammunition available. Virtual training systems are unavailable at the unit level where most of the forward observers reside, and the current global situation has demanded that this skill be used.

Not only are the training systems hard to come by, it is hard to train many observers because of limited resources. For example the TSFO training encompasses a whole room and can only process one forward observer's mission at a time. Although other observers can work up missions, they do not get any actual "stick time" creating a bottleneck in the training pipeline. By building a system that runs on a laptop many observers can train in parallel in that same room and the training system could be used in a deployable environment.

C. RESEARCH QUESTIONS

While, the previous thesis focused on creating a tool to help FO's maintain proficiency, this thesis wanted to validate whether a virtual environment could actually be used to assist in training the call for fire skill. An experiment was conducted to answer this question. The experiment was conducted at the Marine Corps Basic Officer Course to validate the training effectiveness of the system.

Secondly, we wanted to build a system that would run on equipment currently available to the Marines. Free software is no good if you have to buy a $3000.00 computer just to run the software. The Marine Corps is in the process of purchasing suites of laptops for deploying units. Because the Marines will have available laptops it is important for FOPCSim to be able to run on those laptops to make uses of available resources.

Finally, we asked is it possible to add enough functionality to FOPCSim to be used as a networked team trainer without making the system too complex to be used by a single user for training. We were confident we could build a stand alone system, but is it feasible to build a system that can train an artillery battery without needing special contractor support in order to execute the training evolution.

D. ORGANIZATION OF THE THESIS

This thesis is organized in the following chapters:

Chapter I: Introduction. This chapter gives a basic overview of the work contained in this thesis and the problem the authors are trying to solve.

Chapter II: Background. This chapter focuses on the forward observer trainers that have been recently fielded or are under development.

Chapter III: Cognitive Task Analysis: A CTA of the tasks that a forward observer performs and how that maps to FOPCSim.

Chapter IV: Requirements. This chapter covers the requirements for FOPCSim.

Chapter V: System Development. This chapter covers the development process and the design decisions made when developing the system.

Chapter VI: Experiment.

Chapter VII: Results.

Chapter VIII: Conclusions

Chapter IX: Future Work

II. BACKGROUND

A. INTRODUCTION

Speaking at the Small Unit Excellence Conference in May of 2005, retired General Al Gray, former Commandant of the Marine Corps, stated that "Every sergeant ought to be able to call in close-naval gunfire and close-air support, Tomahawks and anything else that's out there on the battlefield – without exception."[1] In order for a Marine to develop the skills needed to call in supporting arms requires class room instruction as well as practical application of the procedure. Unfortunately there is not enough ammunition available to train every officer and every sergeant and above to become proficient in these tasks. However, the Marine Corps does use simulation in order to prepare individuals for the infrequent but valuable live fire training.

In order to develop and maintain proficiency as an artillery forward observer the Training Set, Fire Observation (TSFO) has been used by both the schoolhouses and Marines in the operating forces. Unfortunately this antiquated system offers little variability to the instructor or students. There are several newer systems in use and being developed by the Army, Navy, and Marine Corps.

While developing FOPCSim, we tried to take the most beneficial features of these newer systems and include them in our design. Our goal was to develop a complementary training system which allows the users and trainers to benefit from including FOPCSim in their training.

B. CURRENT TRAINING SYSTEMS

1. Training Set Fire Observation (TSFO)

The TSFO is one of the oldest simulations still in use in the Marine Corps. It can still be found on most major bases, although it is being phased out to make way for newer systems.

According to FM 6-30, the TSFO

[1] Bailey, L. "U.S. Marine Corps chiefs call for squad-leader training", *Training & Simulation Journal*, p 14, June/July 2005.

> …was designed to permit realistic instruction to forward observers in the observation and adjustment of artillery fire and fire planning. The TSFO simulates the visual and sound effects that a FO can expect to experience at an observation post (OP) when overlooking a typical battlefield. The TSFO can also be used for exercise planning, basic and advanced map reading, and terrain recognition training. The TSFO can simulate the effects of four 8-gun batteries, each equipped with 155-mm howitzers with a variety of ammunition types including HE/Q, HE/VT, HE/ti, smoke, and illum. A variety of targets can also be simulated. These include machine guns, wheeled and tracked vehicles, and helicopters. The entire system can be operated by one person. The TSFO simulates the visual and sound effects of artillery fire on terrain views projected on a classroom screen. A series of computer-controlled slide projectors provides terrain views as seen from a variety of OP's, and burst simulation of the number, type, location, and pattern of rounds called for in the call for fire. The sound system is controlled by the computer. It is programmed to realistically portray the sounds typically generated by artillery rounds in flight and at the moment of impact. The sound level may be controlled by the operator to realistically tailor the sound to the size of the classroom and number of observers being instructed. The TSFO can simulate day and night battlefield operations as well as visual characteristics of smoke and illuminating ammunition, including the effects of drift caused by wind speed and direction.[2]

2. M32 Subcaliber Mortar Trainer (Lawndarts)

The M32 Subcaliber Mortar Trainer commonly known as "Lawndarts" is one of the live simulations that is currently used at The Basic School to train new lieutenants to call for fire. In addition, it can be used by any infantry unit which has 81mm mortars. The system works by inserting a pneumatic sleeve into the 81mm mortar tube. By connecting the insert to a CO_2 bottle the mortars are now capable of shooting the M379 training projectile (a 25mm blue metal dart). In order to train effectively with this system a miniature range can be set up with matching maps. With this setup, both forward observers and mortarmen get training simultaneously. The observers are usually sitting within feet of the mortar crews around the miniature range, so are able to observe the crew and their procedures. By observing the procedures and the complete trajectory of the miniature projectile, students are able to gain insight into the entire process of calling for fire. The technical manual for the trainer is the TM 9692021214.

[2] Headquarters, Department of the Army, Washington, D.C., FM 6-30 Tactics, Techniques and Procedures for Observed Fire (U.S. Army Doctrinal Publication (1991), Appendix C-4.

3. Guard Unit Armory Device Full-Crew Interactive Simulation Trainer (GUARDFIST II)

Guardfist II (see Figure 1.) is a simulation currently in use in both the active duty Army and the Army Reserve. Guardfist II

> …is a transportable training system that will provide simulated battlefield scenarios for the training of Field Artillery Forward Observers (FOs) task. There are three versions of the system: 1:1 version includes one Instructor Station and one Forward Observer station wherein one instructor trains one Forward Observer. The 1:4 version comprises one Instructor Station physically connected to the four Forward Observer Stations. In this version, one instructor can train four students. The 1:30 version comprises one Instructor Station physically connected to the 30 Forward Observer Stations. In this wide screen version, one instructor can train 30 students.[3]

Figure 1. Guard Unit Armory Device Full-Crew Interactive Simulation Trainer ([From Ref. [3].)

4. Call-For-Fire Trainer (CFFT)

The Call-for-fire trainer (see Figure 2.) is the Army's newest virtual supporting arms trainer. It was developed as a replacement for both the TSFO and Guardfist II. It is

[3] U.S. Army Program Executive Office for Simulation, Training, & Instrumentation (PEO-STRI), Guard Unit Armory Device Full-Crew Interactive Simulation Trainer (GUARDFIST II) (online),<http://www.peostri.army.mil/PRODUCTS/FS-CATT/> Available (August 2005)

capable of training all supporting arms to include artillery, mortars, naval gunfire and CAS. According to Col. Mitchell, Director of the Training and Doctrine Directorate (DOTD) and G3 of the Field Artillery Center and Fort Sill, Oklahoma, CFFT

> gives the field a cutting-edge trainer to teach and maintain observer skills throughout the force and, because of the pressing need, fielding has been pushed to the right. In fact, Fort Sill teamed with the Program Executive Office for Simulation, Training and Instrumentation (PEO-STRI) to push this program through, from writing the requirements document to first production models, in less than two years—a tremendous success story.[4]

Figure 2. Call For Fire Trainer (CFFT) Setup ([From Ref. [4].)

This trainer also comes in multiple configurations similar to the Guardfist II to include: 1:4, 1:12, and 1:30 instructor to student ratio. "The 1:4 and 1:12 systems are fully deployable and take about 20 minutes for an experienced operator to set up in any classroom."[5] CFFT takes advantage of other DoD simulations for content creation;

[4] Mitchell, S. "Call-for-Fire Trainer and the Joint Fires Observer", *Field Artillery Journal,* March/April 2005, pp. 16-17.

[5] Ibid, p. 16.

> the CFFT incorporates the Army's new one semiautomated force (OneSAF) constructive simulation as a force generation tool capable of creating any type of friendly, enemy or neutral force the commander or instructor desires. The SAF mission profiles can be saved as scenario files to be used repeatedly as well as modified to suit any number of operational and training requirements.[6]

The CFFT is currently being fielded as a pre-production item and in use at several different schools at Ft. Sill. It also incorporates simulated forward observer tools such as laser range finders and designators.

5. Indoor Simulated Marksmanship Trainer- Enhanced (ISMT-E)

The Indoor Simulated Marksmanship Trainer-Enhanced is primarily used as a marksmanship trainer throughout the Marine Corps. ISMT's are fielded across the Marine Corps at formal schools, infantry regiments, the wing, MSG, Security Forces, and Reserve locations.[7]

The ISMT-E forward observer training package is being deployed as a replacement for the TSFO system.[8] The system is normally set up in a classroom environment and uses a projector to display the range to the students (see Figure 3). The students give a voice call for fire to the instructor running the class as well as the operator of the system. The operator can either be a contractor or a Marine trained to use the ISMT-E.

---

[6] Mitchell, S. "Call-for-Fire Trainer and the Joint Fires Observer", *Field Artillery Journal,* March/April 2005, p.16.

[7] Program Manager for Training Systems (PM TRASYS), Marine Corps Systems Command, Indoor Simulated Marksmanship Trainer – Enhanced (ISMT-E), (online) <http://www.marcorsyscom.usmc.mil/trasys/trasysweb.nsf/All/Indoor%20Simulated%20Marksmanship%20Trainer%20-%20Enhanced%20(ISMT-E)> Available (August 2005).

[8] Agg, J. Cpl, "TBS fire support training comes to life", (online) <http://www.marines.mil/marinelink/mcn2000.nsf/0/63ED1E64C546EDE785257030006396C6?opendocument> Available (September 2005).

Figure 3. Marine using ISMT-E at TBS, Quantico VA ([From Ref. [8].)

6. Forward Observer Training System (FOTS)

The Forward Observer Training System (FOTS) is a program that was developed by NAVAIR, Training Systems Division for use at the Expeditionary Warfare Training Groups, Pacific and Atlantic (EWTGPAC and EWTGLANT) to train both Navy and Marine forward observers and naval gunfire spotters.

This advanced system is normally run in a standard classroom setup with an instructor to student ratio of 16:1 (see Figure 4). The system includes a voice recognition input and synthesized speech output system that allows students to give the call for fire just as they would doing an actual "voice" call for fire. The voice system does have a training period associated with it in order to get it to recognize each student's voice, and the feedback from students has been mostly positive.

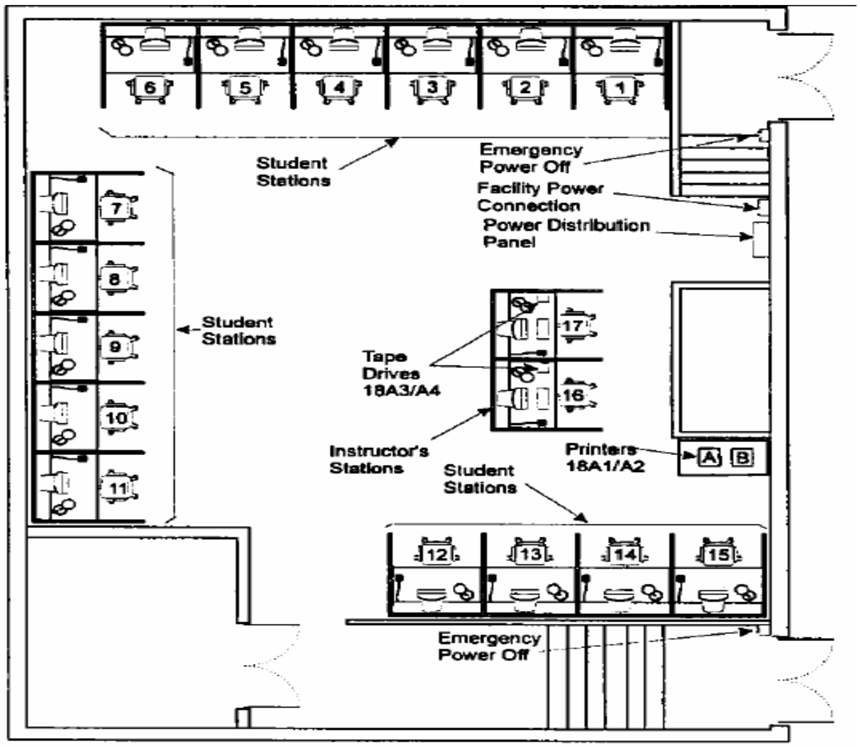


Figure 4. Forward Observer Training System (FOTS) 16:1 Layout ([From Ref. [9].)

The system allows instructors to create and modify scenarios to fit training needs. The system scores the students' missions and provides feedback through an automated tutor. Instructors can monitor all of the student's progress from either of the two instructor stations. By storing all missions by student name, the instructors can evaluate a student's progress over time.[9]

This system is used in conjunction with the ISMT-E to provide training to enlisted Marine Fire Supportmen (MOS 0861) at EWTGPAC. In the ISMT-E training, the students are able to hear the critique of their fellow students in the classroom setting as the students go through missions one at a time in front of the instructor and his classmates. Conversely, using FOTS each student gets to repetitively practice call for

[9] NAVAIR, Training Systems Division, Summary of Forward Observer Training System (FOTS), January 1998, (online), <http://www.ntsc.navy.mil/Files/DEVICE_INVENTORY/Final//16C82.pdf> Available (September 2005).

fire missions at their own pace with instructor input when needed. These two systems are used in a complementary setting in order to gain benefit from both methods of instruction.

7. JOINT FIRES AND EFFECTS TRAINER SYSTEM (JFETS)

The Joint Fires and Effects Trainer System is a prototype immersive training system currently being developed at The Field Artillery School, Ft. Sill, OK in conjunction with the Institute for Creative Technologies, University of Southern California. This system is to be used in conjunction with the CFFT in order to further develop the skills and decision making abilities of forward observers and universal observers.

According to Major General Michael D. Maples, U.S. Army, Chief of Field Artillery,

> JFETS will consist of three primary training modules. The open terrain module (OTM) (see Figure 5) will enable the universal observer to master the skills to sense High Pay Off Targets (HPTs) and engage adversaries with an appropriate mix of joint fires and effects. The urban terrain module (UTM) will train the employment of fires and effects in complex urban terrain while requiring the observer to limit collateral damage and avoid noncombatant casualties. The fires and effects command module (FECM) will train commanders and battle staffs to plan and coordinate the application of lethal and nonlethal joint fires, thus enabling joint, interagency and multinational fires and effects integration.[10]

[10] Maples, M. "Relevant and ready", *Field Artillery Journal*, November/December 2003, pp 1-5.

The Joint Fires and Effects Trainer (JFETS) System Open Terrain Module (OTM). To train universal observers, the OTM has a 150-degree screen that is 15 feet high by 30 feet wide, with easily changeable battle scenarios. JFETS incorporates real-time, photo-realistic graphics, surround sound and artificial intelligence. Service members should begin training on mounted and dismounted calls-for-fire using the system in 2006.

Figure 5. Joint Fires and Effects Trainer System (JFETS) Open Terrain Module (OTM) ([From Ref. [10].)

8. Deployed Virtual Training Environment (DVTE) and Virtual Technologies and Environments (VIRTE)

The Deployed Virtual Training Environment is a program of record sponsored by Training and Education Command (TECOM) to provide a deployable, training system that provides combined arms MAGTF and Naval Integration training and rehearsal capability to the Marine Expeditionary Unit (MEU) and below. Different stations (see Figure 6) can be a ground or air vehicles, FO/FAC, FDC, command station with operation picture, or a Semi-Automated Force (SAF) model to adjudicate interactions and provide additional weapons systems or units. DVTE is a Virtual Simulation component of the USMC JNTC strategy and a member of the JNTC Federation. "The purpose of the project is to develop a flexible, deployable, training system that addresses requirements for combined arms MAGTF and Naval Integration training."[11] FOPCSim and the Delta3D game engine are being considered for inclusion in the suit of systems for DVTE.

[11] Technology Division, Training & Education Command (TECOM), Deployed Virtual Training Environment (DVTE), (online) <http://www.tecom.usmc.mil/techdiv/dvte.htm> Available (August 2005).

Figure 6. DVTE Example Setup ([From Ref. [11].)

Virtual Technologies and Environments (VIRTE) is an ONR research project which provided funding for research and travel during the FOPCSim 2 project. VIRTE sponsors projects looking at the use of virtual environments for military applications. DVTE is one of the potential beneficiaries of the research done under the VIRTE program.

C. FOPCSIM 1

FOPCSim 1 was a forward observer simulator created in 2002 by Brannon and Villandre that would run on a PC.[12] The main feature of this system was that it would run on most PCs in a deployable environment. It was also designed using a cognitive task analysis to ensure that the system simulated the proper tasks. This system was only a prototype, and served as our stepping off point for this thesis. The two major downfalls of this system were the expensive run time license fee incurred from the uses of a commercial graphics engine and a poor user interface. Many of the basic concepts of this system were used in FOPCSim 2.

D. INFLUENCES ON DESIGN

When designing FOPCSim it was very important that we examined the other forward observer simulators in use. Our final version was most closely molded after FOTS. Like FOTS we were focused on repetitive, individual user training. Due to

[12] Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator*, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 2002, p. 53.

available resources and time, we were unable to include a voice recognition system. The one advantage to this is that the users do not need any additional peripherals to input a call for fire mission.

In the end we did not limit FOPCSim to individual training. We wanted the system to also be able to support class room training like the ISMT-E and TSFO. We are not advocating FOPCSim as a replacement but as a viable alternative to these systems. FOPCSim includes an instructor mode that allows it to perform the role as a classroom trainer and the experiment conducted with FOPCSim validates its effectiveness in this role.

Some of the additional features that were added to FOPCSim were the ability to connect to large scale HLA simulations and the ability to connect to AFATDS which gives FOPCSim the ability to function as a team trainer within an artillery battery. By including all these various features, small unit leaders have the ability to use a simulator at no cost to fit their specific training needs.

THIS PAGE INTENTIONALLY LEFT BLANK

III. TASK ANALYSIS

A. BACKGROUND

In order to develop and build a task trainer that has a positive training transfer it is essential that the actual task to be trained is thoroughly explored and the trainer effectively models this task. In order to do this, Brannon and Villandre did a very thorough cognitive task analysis on the call for fire procedure performed by a forward observer when they originally developed FOPCSim. They used the GOMS model in their analysis to model the Goal, Operators, Methods, and Selection Rules for the task.[13] Brannon & Villandre did both a Unit Level Task Analysis to describe the overall tasks of a forward observer and then a more detailed level task analysis of the call for fire (see Appendix A).

Using this detailed task analysis as a starting point, we conducted a Human Abilities Requirement Assessment to evaluate how well FOPCSim maps to the actual event.[14] Based on the Fleischman Job Analysis Survey,[15] we examined each element of the detailed task analysis for the actual call for fire and determined what human abilities are required to perform those elements. After doing the same thing for performing the task using FOPCSim we were able to determine where a mismatch occurred between the live world and the simulation.

By doing this evaluation, we not only ensured we designed the system to maintain fidelity with the real world task wherever possible, we also could evaluate those areas it did not. We therefore can place realistic bounds on what tasks FOPCSim effectively models and what tasks it should be used to train.

[13] Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator*, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 2002, p. 17.

[14] Cockayne, W. & Darken, R.P. (2003). The Application of Human Ability Requirements to Virtual Environment Interface Design and Evaluation. *Handbook of Task Analysis for Human-Computer Interaction*. Diaper, D. & Stanton, N. Eds., pp. 401-422.

[15] Fleishman, E., & Quaintance, M. (1984). *Taxonomies of human performance: The description of human tasks*. Orlando, FL: Academic Press.

B. MAPPING OF TASK ANALYSIS TO FOPCSIM

By mapping the cognitive task analysis of the actual call for fire to the simulation we are able to identify areas where the simulation maintains fidelity to the real task and those areas it does not. The best way to demonstrate this mapping is by presenting a scenario that a forward observer would go through using FOPCSim. The numbers in parentheses refer to the tasks in the task hierarchy (see Appendix A).

Prior to entering a scenario the user can select from various options including what tools he will have available, time of day, and whether or not the mission is scored. Upon initiation of the scenario the observer is required to send a position report (posrep) to the FDC.

The first step the observer must do is self-location (1.0).

(1.1) The observer can select from various choices to do this:

(1.1.1) Use the GPS (if enabled)

(1.1.2) Utilize the map and compass to do resection or terrain association

(1.1.3) Utilize the laser range finder (if enabled) to aid in resection

Once the observer has successfully determined his location he transmits his posrep to the FDC. If the posrep is not within 200 meters of the actual posrep then he will have to resend the posrep until it is within range. Targets can be placed on key terrain in order to aid the observer in doing a resection.

After the posrep is sent the observer can then begin engaging targets using the call for fire (3.2).

The six elements of the call for fire are sent in three transmissions just as in the real task. The user selects the different elements from a series of drop down lists and editable text boxes. For the first transmission the observer sends the observer identification (3.2.1) and the warning order (3.2.2).

"Kilo battery this is A2W adjust fire, polar, over" (3.2.1, 3.2.2.1.1, 3.2.2.3.2)

The second transmission consists of the third element of the call for fire: the target location (3.2.3).

"Direction 0400, Distance 600, Down 40, Over" (3.2.3.2)

The third transmission contains the remaining three elements of the call for fire: the target description (3.2.4), the method of engagement (3.2.5), and the method of fire and control (3.2.6).

"3 T-72's in the open, ICM in effect, At my command, Over"

After receiving and sending back the Message to Observer (MTO), the observer stands by to spot the initial adjusting round. He can use his binoculars to determine where the round landed in relation to the target. In addition, he needs to determine the Observer-Target Factor (OT Factor) in order to determine the range correction. Once the observer has made the spotting and determined his correction he sends it.

"Left 30, Add 200, Over" (3.2.13.1, 3.2.13.2)

When the observer has achieved effects on target or broken the 100 meter bracket he will enter the fire for effect (FFE) stage of the mission. The observer can then either send his End of Mission Statement consisting of Refinement, Record as target, End of Mission, Surveillance (RREMS) or repeat the FFE if the desired effects were not achieved.

While developing FOPCSim we made a special effort to map all elements of the basic Call for Fire as laid out in the task analysis. However, there are some elements of certain sub-tasks that we chose not to put in the simulation. Elements in green in Table 5 Appendix A3 are modeled in FOPCSim, whereas those in red are not. The primary reason we chose not to put certain sub-tasks in this version is they are beyond the scope of the "basic" call for fire. An example of this is Suppression of Enemy Air Defense (SEAD). SEAD is an advanced call for fire technique employed by observers that involves the synchronizing of artillery or mortar rounds on a target in conjunction with aircraft delivering effects on another target in close proximity. Although modeling this task in a simulation is valuable, it was beyond the scope of the current project. There

were other elements of the overall task that were not included based on the decision to "stick to the basics" and not clutter the user interface. When an observer sends in subsequent adjustments in order to get rounds on target there are fifteen possible elements that he can send. Normally, the observer will only send two or three of these elements. For this version we chose to model only nine of the fifteen most common elements.

Through future development the remaining elements of the call for fire could be accurately and effectively modeled for inclusion in FOPCSim. See Chapter IX for more information on future work.

C. HUMAN ABILITIES REQUIREMENTS ABSENCE/ PRESENCE TEST

After a thorough review of the cognitive task analysis that had already been conducted by Brannon and Villandre, we then took it one step further and looked at what human abilities the observer uses at each of those steps. The technique used was based on the technique described by Cockayne and Darken in Reference 14.

The process of evaluating FOPCSim using Human Ability Requirements (HAR) was a four part process. The first step was to list all of the human abilities that are required to conduct a Call for Fire in the real world. To do this we used the Fleischman Job Survey to identify the skills required to conduct the Call for Fire.[16]. We then looked in detail at each step identified in the CTA and determined which of the human abilities are required for that specific step. After completing the process for the real world task, the next step is to determine what human abilities are required to complete the task in the virtual world. To do this we used the abilities needed to conduct the task in the real world as a starting point and again looked at each step of the CTA for FOPCSim. The final step in this process is to compare the HAR from the real world and the virtual world for differences.

While looking at the CFF, we identified 27 skills that were needed to perform this task in the real world. Of those skills twelve of them were cognitive, three were psychomotor, ten were sensory/ perceptual and two involved specific knowledge or

[16] Fleishman, E. "Rating Scale Booklet, Fleishman Job Analysis Survey", Management Research Institute Inc., 1995.

skills. These abilities include such things as: oral comprehension, mathematical reasoning and depth perception (see Appendix B for a complete listing of the skills). When comparing the human abilities required to Call for Fire in the real world versus in the simulation we found the largest differences in the psychomotor and sensory/ perceptual categories, whereas the task remained matched very well in cognitive abilities.

The first major discrepancy noted was the lack of Far Vision and Depth Perception needed for the computer simulation. This is obviously due to the fact you are looking at a two dimensional representation on a computer screen versus looking out (in three dimensions) over open terrain. Although Far Vision and Depth Perception are not used when looking at a screen, Near Vision skills are required to pick out a small target on a screen as well as to judge whetheran impact was in front of or behind a target. The clues that are seen on the screen (occlusion and size difference) allow the user to develop the same information as they would if seeing things in the real world.

The disparity in vision requirements may cause the biggest challenge while using the simulation for the task of self-location. The real world task involves comparing what you see around you to what is on the map using a compass as an aid to determine your location. Brannon and Villandre incorporated tests of this task into their experiment with mostly positive results. Here it is important to achieve the best fidelity possible between what the user sees and the actual terrain.

Another difference involves the use of Night Vision. The simulation can simulate low light conditions and the use of night vision devices; however it is not the same physical ability as actually seeing at night. For training purposes, the question is: Is it "good enough"? The answer revolves around how important this ability is to the overall task. The user must understand that although the program simulates night operations, it does not completely replicate the environment and the physical requirements that are demanded of the eye to see at night.

The major auditory difference between the simulation and the actual Call for Fire, is the way you communicate. When conducting an actual CFF you talk into a handset attached to a radio, for the simulation you use a mouse and keyboard as entry devices.

We have included pre-recorded voice files for some messages, which does require the observer to use oral comprehension, but not as much as in the real world. This aspect could be further developed to incorporate complete speech recognition and replication software as is used in FOTS (see Chapter II). For our thesis we chose not to pursue this direction in order to keep FOPCSim light weight and simple to use. Again the question is: What is “good enough”? A simple approach to overcome this limitation would be to have the trainee say his CFF to someone operating FOPCSim who would give a read back similar to what occurs during the actual event. This exact technique was used in a networked environment where the observer gave an actual voice call for fire to an Advanced Field Artillery Tactical Data System (AFATDS) operator just as would be done in the real world. The observer then observed the impacts of his rounds using FOPCSim.

Another difference is the inability to use sound localization as effectively. This skill is required when an impact is not seen due to terrain masking. This limitation could be improved through the use of spatialized sound to give the user some clue as to where the sound came from.

The program does a good job of replicating the views seen using different devices that a forward observer uses to attack a target (Binoculars and Laser Range Finder). However something it doesn’t replicate is the Arm Hand Steadiness required to hold a compass or laser range finder steady in order to get an accurate reading. This skill could be replicated through the use of mock binoculars that are incorporated into the system. This would also help the observer practice changing from the aided to unaided view and back while spotting rounds. Since FOPCSim does not effectively model this, we would not recommend using FOPCSim to teach the specific skill of reading a compass or of using binoculars to spot for artillery. This skill is better learned using the actual equipment in a field setting.

FOPCSim keeps a very high level of fidelity in the mapping of cognitive tasks. Brannon and Villandre stated:

> When a target is identified, the FOPCSim user must perform the same steps to determine target location and formulate the call for fire as they

> would in the real world. FOPCSim maintains cognitive fidelity to the real task, but sacrifices physical fidelity. The performance differences are due to the physical interface and not the cognitive element.[17]

The Call for Fire was designed to be a very concise means of communication with little room for deviation; this lends itself well to being simulated on a computer. The same cognitive tasks required to get rounds on target in the real world are required to do it in the simulation.

This high level of fidelity that was started with the original version of FOPCSim has been maintained in the newer version as well. As seen with the example mission above, the user must go through the same thought process as he would in the real world when deciding what type of mission to fire, how to construct the CFF, and how to convert the spottings into corrections. In order to test whether our technique for development using the CTA and human abilities requirements (HAR) evaluation was successful we conducted an experiment to explore FOPCSim's performance (see Chapters VI and VII) .

[17] Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator*, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 2002, p. 99.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. REQUIREMENTS

A. OVERVIEW

The following requirements are adapted from the original requirements of Brannon and Villandre for FOPCSim 1. They have been updated based on the use of the Delta3D engine and other technology changes.

The Forward Observer PC Simulator (FOPCSim) supports the task training of the artillery call for fire (CFF) for forward observers. FOPCSim provides the capability for integrated training in the conduct of observed fire missions in support of Marine forces to increase the using unit's warfighting capability. FOPCSim will greatly enhance the capability of our forces to destroy, degrade and delay enemy forces by providing an effective means for enhancing Marine proficiency in the employment of indirect fires. FOPCSim will allow forward observer personnel to train in a stand-alone environment without the use of live ammunition.

The Forward Observer PC Simulator (FOPCSim) system will use simulation technology to immerse the FO team into realistic interactive training scenarios. This system will be capable of operating as a stand alone system, a classroom configuration, and in deployed environments. The FOPCSim will have the capability to connect to the Advanced Field Artillery Tactical Data System (AFATDS) through a gateway and integration with the Joint Semi-Automated Forces (JSAF) simulation. This will allow simultaneous training of forward observers and fire direction center (FDC) personnel. The FOPCSim will primarily be used in garrison with the capability to be transported and deployed to field environments. The FOPCSim classroom configuration will be designed as a possible replacement for the Training Set Fire Observation (TSFO) system. The shipboard deployable configuration will consist of a FOPCSim with a reduced footprint (most likely a laptop configuration) to be used on ship.

B. SUMMARY OF CAPABILITIES

1. Capabilities

The following table summarizes the capabilities of FOPCSim 2 and the proposed benefits of each capability.

Table 1. Summary of System Capabilities

Supporting Feature	Benefit
FO Self location	USMC performance standard, improves user competence
Target Location	USMC performance standard, improves user competence
Call for Fire Procedures	USMC performance standard, improves user competence
Employment of munitions and fuzes	USMC performance standard, improves user competence, some munitions not trainable on current ranges, low cost
Utilization of all T/O equipment	USMC performance standard, improves user competence, some equipment not trainable on current ranges, low cost

2. System Requirements

The following are the system requirements in order to effectively run FOPCSim.

Processor: 1 GHz PIII minimum

Memory: 512 MB minimum; 1 GB preferred

Disk Space: 2 GB to install

Graphics Card: 128 MB ATI 9800, or similar card capable of supporting OpenGL;

Operating System: Windows 2000/XP.

Sound: OpenAudio software (http://www.openal.org/downloads.html)

C. REQUIREMENTS

The original requirements for FOPCSim 1 were based on the Operational Requirements Document for the Closed Loop Artillery Training System (CLASS). We have modified those original requirements based on the scope of our project.[18]

1.0 Functional Requirements

[18] Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator*, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 2002, p. 56-70.

1.1 FOPCSim shall provide the capability to monitor, score, and evaluate trainee's performance using Ft Sill grading standards as a template.

1.2 FOPCSim shall allow the initialization and activation of the simulator into individual training scenarios and higher level training scenarios using HLA connectivity.

1.3 FOPCSim shall provide emulated (i.e., computer generated) forces capable of reacting to indirect fire.

1.4 The FOPCSim simulation shall replicate both enemy and friendly forces including tanks, trucks, personnel carriers, command and control vehicles, reconnaissance vehicles, forward area air defense weapons, dismounted infantry with their associated weapons, mortars, artillery and rockets.

1.5 Friendly effects of indirect fire and rotary-wing and fixed-wing close air support shall be replicated.

1.6 FOPCSim shall permit users to design new scenarios and revise existing scenarios.

1.7 FOPCSim shall provide the capability to generate new scenarios for the ultimate purpose of mission rehearsal.

1.8 FOPCSim shall provide the capability to place targets and friendly units at specified coordinates on the simulated terrain. Input screen allows user to enter number, type, location of targets, whether they are moving or not, whether they are displayed sequentially or all at once.

1.9 FOPCSim simulated terrain and environment shall be provided with the following:

1.9.1 Terrain database utilization shall be capable of using digital data available through the National Imagery and Mapping Agency (NIMA) to include Digital Terrain Elevation Data (DTED) (threshold) and other Geographic Information System (GIS) and Remotely Sensed Imagery (RSI) sources (objective). The terrain database format shall allow interoperability with other FOPCSim simulators for future use as a distributed application.

1.9.2 Be able to represent significant and distinguishable terrain features from the observer to the horizon.

1.9.3 Simulate terrain that represents features such as hilltops, valleys, saddles, ridges, depressions, gullies, streams, trails, hillocks, mountains, rivers, fords, forests, roads, man-made structures, built up areas, vegetation, and aquatic features representative of these areas. Features shall be displayed with sufficient fidelity to allow recognition by shape, size, and relationship to other objects and texture. The database shall be selectable at initialization.

1.9.4 FOPCSim shall have the capability to input additional terrain databases (threshold) and provide a means to modify terrain databases and generate new terrain databases (objective).

1.9.5 The following image quality requirements shall apply as a total contribution to the complete integrated visual system (terrain database, image generation system and visual system). Provide the full spectrum of day and night visibility to include sunlight and moonlight effects on terrain. Provide for reduced visibility due to smoke, dust, fog, rain, glare, shadows, snow and other likely battlefield conditions. Visual resolution of the simulated terrain shall ensure a true perspective is maintained when distance to an object increases or decreases. The visual system shall be capable of displaying personnel, vehicles, and weapon effects. Objects shall appear in proper size with distinguishing characteristics for the indicated range as viewed through the replicated sighting devices. Terrain feature clarity shall be sufficient to provide appropriate depth perception and distant vision.

1.10 The FOPCSim system shall train and evaluate forward observers. The FOPCSim will also provide the capability to exercise combined arms to train fire support teams (objective using HLA). The three different FOPCSim configurations will use the same software.

1.11 The FOPCSim will be used to train tasks/events listed in MCO 3501.26, Artillery Unit Training and Readiness (T&R) manual dated 11 April 2000, MCO 1510.35D Individual Training

Standards (ITS) for Infantry (Enlisted) Occupational Field dated 5 April 1999, MCO 3501.3C Marine Corps Combat Readiness Evaluation System (MCCRES) Volume II, Infantry Units.

1.12 The FOPCSim shall replicate Laser Range Finder/Designator Equipment (e.g., MULE, TLDHS, and AN/GVS-5), to include target observation, fixed and moving target tracking skills.

1.13 The FOPCSim shall simulate shell bursts to include sound effects of the required projectiles, anywhere in the target area with an observer-target distance of six (6) kilometers (threshold) or twelve (12) kilometers (objective).

1.14 The FOPCSim shall simulate subsequent bursts, specified adjustment correction data given by the forward observer, until a fire for effect or target kill is achieved. Adjustments shall accommodate single gun, single round missions through multiple guns/multiple rounds/multiple (projectile type/fuse type) missions with a threshold of up to 6 guns.

1.15 The FOPCSim shall measure and record the call for fire, the distance between the target and the impact point of the round/s.

1.16 The FOPCSim shall simulate various ground and environmental conditions affecting munition impacts (e.g. concrete, smoke, fog, rain, snow, blowing sand, vegetation). These conditions shall affect munitions impacts.

1.17 The FOPCSim shall provide for basic, advanced, and sustainment artillery training levels to include fire support planning at the basic level.

1.18 Forward observer calls for fire and the adjustment of fires shall be entered as keyboard inputs to replicate voice procedures. Use of digital input system (DCT replacement) (Future).

1.19 The FOPCSim shall incorporate center gun and adjustment for final protective fire missions.

1.20 The FOPCSim shall simulate smoke screens drifting in a manner appropriate for a 0-20 mph wind and for variable winds to cover all directions (360 degrees).

1.21 The FOPCSim shall simulate illumination and coordinated illumination missions drifting in a manner appropriate for steady and variable winds up to 20 mph.

1.22 The FOPCSim shall determine when rounds or moving targets shall be sensed as unobserved or lost due to the effect of terrain elevation features or obscured visibility.

1.23 The FOPCSim shall provide Height of Burst (HOB) variations and the ability to adjust HOB for smoke, illumination, and area adjust fire missions and high explosive/mechanical time (HE/MT). Variable HOB to include simulation of air burst without ground effect, air burst with ground effect and mixed bursts of both air and ground effects to include any direction and speed.

1.24 The FOPCSim shall provide simulated air, graze, and mixed bursts accurate to scale and size with respect to the observer-target range.

1.25 The FOPCSim shall delay the distribution of rounds by ten (10) seconds between subsequent volleys for multiple round missions.

1.26 The FOPCSim shall simulate time of flight of both low and high angle fire missions. The user may select a compressed time of flight option upon initialization.

1.27 The FOPCSim shall incorporate the use of simulated lasers by forward observers in the conduct of any fire mission.

1.28 The FOPCSim shall provide the ability to conduct simultaneous simulation for supporting arms with rotary wing or fixed wing close air support in order to conduct combined arms training using HLA connectivity.

1.29 The FOPCSim stations will include full function simulation of the following equipment with the latest technology: binoculars, compass with mils and degrees, lasers and GPS.

1.30 The field of view shall be 45 degrees (threshold). The user will have the ability to rotate their field of view laterally to achieve 360 degrees of visibility. The user will also be able to rotate their field of view 90 degrees up and down to achieve 180 degrees vertical field of view.

1.31 The FOPCSim shall replicate massing of fires at the battery level.

1.32 The FOPCSim shall provide immediate after action review for a given training session (threshold) and archive training data for all students as historical data to focus future training (objective).

1.33 The FOPCSim shall be provided with the means to produce reports and to transfer, create, delete and manage student files.

1.34 The FOPCSim shall be capable of fully managing the following FOPCSim combinations shown below: Subsystems Threshold: 1 Objective: 3

1.35 The FOPCSim shall be able to freeze a moving target.

1.36 The FOPCSim shall provide mission replay in which all previous rounds fired during a mission can be easily recalled and repeated.

1.37 The FOPCSim shall provide an instructor tutorial guide/demonstration program.

1.38 The FOPCSim shall provide the instructor the capability to create realistic tactical scenarios and interact with them in real time.

1.39 The FOPCSim shall compute "did-hit" grid location and height of burst (HOB) for each weapon and mean point of impact and HOB for each fire mission.

1.40 The FOPCSim shall perform all known and future types of fire missions.

1.41 The FOPCSim shall provide the functions needed to initialize and control the training exercise. The user will have the ability to reenter incorrect data.

1.42 The FOPCSim shall record data with a time-stamp in order to identify significant points during the playback to highlight and illustrate lessons learned.

1.43 The FOPCSim shall provide a means to initiate and terminate the training exercise.

1.44 Degraded modes will be selectable by the FOPCSim at initialization and any part of the exercise. Examples include ammunition status, navigation malfunctions, communications problems, no binoculars, etc.

2.0 Nonfunctional Requirements

2.1 Usability

2.1.1 The FOPCSim shall train and evaluate forward observers.

2.1.2 The FOPCSim shall provide the capability to exercise combined arms to train fire support teams using HLA connectivity.

2.1.3 Employment Tactics. FOPCSim shall be operational in garrison and field environments, FOPCSim classroom environments (TSFO replacement) and aboard amphibious ships. This will make FOPCSim available to all locations throughout the world where Marines are stationed with the appropriate weapons systems.

2.1.4 Employment Prerequisites. FOPCSim shall not require special support requirements such as site preparation, storage facilities or changes to other items of equipment at the time of Initial Operational Capability (IOC).

2.1.5 Control. FOPCSim can be located at and employed by the individual active duty artillery battalions and regiments, Marine Reserve artillery batteries and Marine Artillery Detachment at the US Army Field Artillery School (USAFAS).

2.1.6 Environmental Conditions. FOPCSim shall be operational and maintainable in all types of climate and terrain where Marines deploy. FOPCSim shall be capable of operating during full exposure to temperatures ranging from 0F to 125F.

2.1.7 Information Warfare. To avoid being susceptible to information warfare, FOPCSim will have the same security safeguards as Marine artillery units and organizations.

2.2 Reliability

2.2.1 FOPCSim shall be reliable, available and maintainable.

2.3 Performance

2.3.1 FOPCSim shall be able to operate in a Stand Alone mode.

2.3.2 FOPCSim shall replicate the actual operational equipment platforms when practical to provide training simulation.

2.3.3 In accordance with DoD Directive 5000.59 all systems currently under development shall be compliant with High Level Architecture (HLA).

2.3.4 FOPCSim shall be designed to maximize the use of commercial-off-the-shelf (COTS) and non-developmental (NDI) hardware and software.

2.3.5 FOPCSim shall realistically replicate all subsystem sound effects, as well as inter-subsystem communication.

2.3.6 FOPCSim shall provide a means to store, modify, and add sound cues to the sound databases as needed.

2.3.7 Subsystem sound effects shall be in proportion to that of the actual weapon operations.

2.3.8 FOPCSim shall simulate the required sensors and controls for each subsystem platform to support required training tasks and tactical exercises.

2.3.9 The training system's sensors and controls shall represent the physical appearance and replicate the performance of each platform's sensors and controls.

2.4 Supportability

2.4.1 FOPCSim shall be designed for ease of preventive maintenance, repair maintenance, and servicing.

2.4.2 Contract maintenance support will be contracted and provided for to the using units at all major commands.

2.4.3 FOPCSim will not require new Marine Corps resources or personnel.

2.4.4 FOPCSim will run on either Windows 2000 or XP with 512mb of RAM.

2.4.5 FOPCSim will require a graphics card with at least 16mb of video RAM.

D. PRODUCT FEATURES

1.0 System Features

1.1 Interactive 3D Graphics

-Simulated representation of actual terrain

-Digitized 1:50,000 map

-Representation of reticule patterns of optical devices

-Toggle up/down for binos

-Representation of GPS and compass

-Pop-up menus when needed for CFF

-“Clipboard” displaying CFF format, filled out as CFF is sent.

1.2 PC Based Application Multi Mode

1.2.1 Individual User Mode

1.2.2 Instructor led Mode

1.3 Keyboard Input for User Action

1.4 Voice Input for User Action (future)

1.5 GUI Input for User Action

1.6 Summary Data to Text File

2.0 Configuration Module

2.1 Specify types, sizes, and location of targets

2.2 Stationary and moving (future) targets

2.3 Choose different terrain sets

2.4 Choose different observation post locations

2.5 Choose lensatic or M2 compass (degrees or mils)

2.6 Allow entry to configuration module during run time

3.0 View Manager Module

3.1 Binocular View

-Toggle between looking over or through binos.

3.2 M2 or lensatic Compass View

3.3 Modular Universal Laser Engagement (MULE) System View Day/ Night

3.4 AN/GVS-5 laser rangefinder View

3.5 Naked Eye View

3.6 NVG's

3.7 TLDHS

4.0 User Actions Fire Mission Procedure

4.1 Choose type of fire mission

4.1.1 Adjust Fire

4.1.2 Fire for Effect

4.1.3 Immediate Suppression

4.1.4 Immediate Smoke

4.2 Choose target location method

4.2.1 Grid

4.2.2 Polar

4.2.3 Shift From Known Point

4.2.4 Laser Polar

4.3 Input target description (Drop down list to pick from)

4.4 Choose method of engagement

4.4.1 HE/Quick

4.4.2 HE/Time

4.4.3 HE/VT

4.4.4 WP

4.4.5 WP M825

4.4.6 ICM

4.4.7 Illumination

4.5 Enter subsequent corrections

4.5.1 Left

4.5.2 Right

4.5.3 Add

4.4.4 Drop

4.5.5 Up

4.5.6 Down

4.6 Enter observer-target (OT) direction

4.7 End the current mission

4.8 Enter Refinements

4.9 Establish known points

4.10 Utilize standard operating procedures (SOPs) for immediate missions

4.11 Allow for sequential viewing of targets.

5.0 After Action Review

5.1 Immediate playback of last mission. (Future)

5.1.1 Playback controls: FF, Pause, Rewind control bar

5.1.2 Show grids/ error for target and each impact

5.2 Save results for later review or print out based on user's name.

5.2.1 Compile results for each user.

THIS PAGE INTENTIONALLY LEFT BLANK

V. SYSTEM DEVELOPMENT

FOPCSim was developed using an iterative process over a 10 month period. Initially four people were involved in the development process: two engineers from the Delta3D development team and the two authors of this thesis. The two Delta3D engineers were crucial to the success of the project because the engine was in the early stages of development and FOPCSim was the first full scale application that utilized all aspects of the engine. Milestones were established for all phases of the development process which ensured that the system would be completed in time for the experiment. There were five main milestones during the development process: Requirements and Design phase, MOVES Open House Demo Release, Interservice/ Industry Training, Simulation & Education Conference (I/ITSEC) Alpha Release, TBS experiment Beta Release, Final NPS Release. By meeting deadlines and goals for each of the milestones, we were able to smoothly turn over the code so that others could continue to develop FOPCSim.

Because the software libraries that were used to develop FOPCSim were free, we were able to distribute the application to users at no cost. As the development cycle advanced we were able to continuously grow our user base for the system, which helped to identify bugs and gather feedback which helped to refine the design.

One of the most important aspects of the development of the system was full access to a subject matter expert (SME) during the entire development of the project. Not only was the SME an artillery officer, but he had been an artillery instructor at TBS. By having a SME with classroom experience it was easy to validate that the system specifications properly adhered to training objectives during the requirement and design phase. During the development phase of the system the SME was testing the latest features to ensure they properly adhered to doctrine. By tightly coupling the SME with developers, communications flowed smoothly and no major reworks of FOPCSim were required. This may be viewed as a unique situation, but by having an SME available during the entire development cycle; it greatly reduced the amount of time validating the different parts of the system for correctness. Appendix C contains a diagram depicting the

system architecture that was developed based on collaboration between the SME and computer programmers. Figure 7 shows how communication flowed between the subject matter experts and software engineers during the development cycle. The phase lead was in charge of performing the majority of the work during that phase while the phase support was providing the input to ensure that all requirements were being properly met.

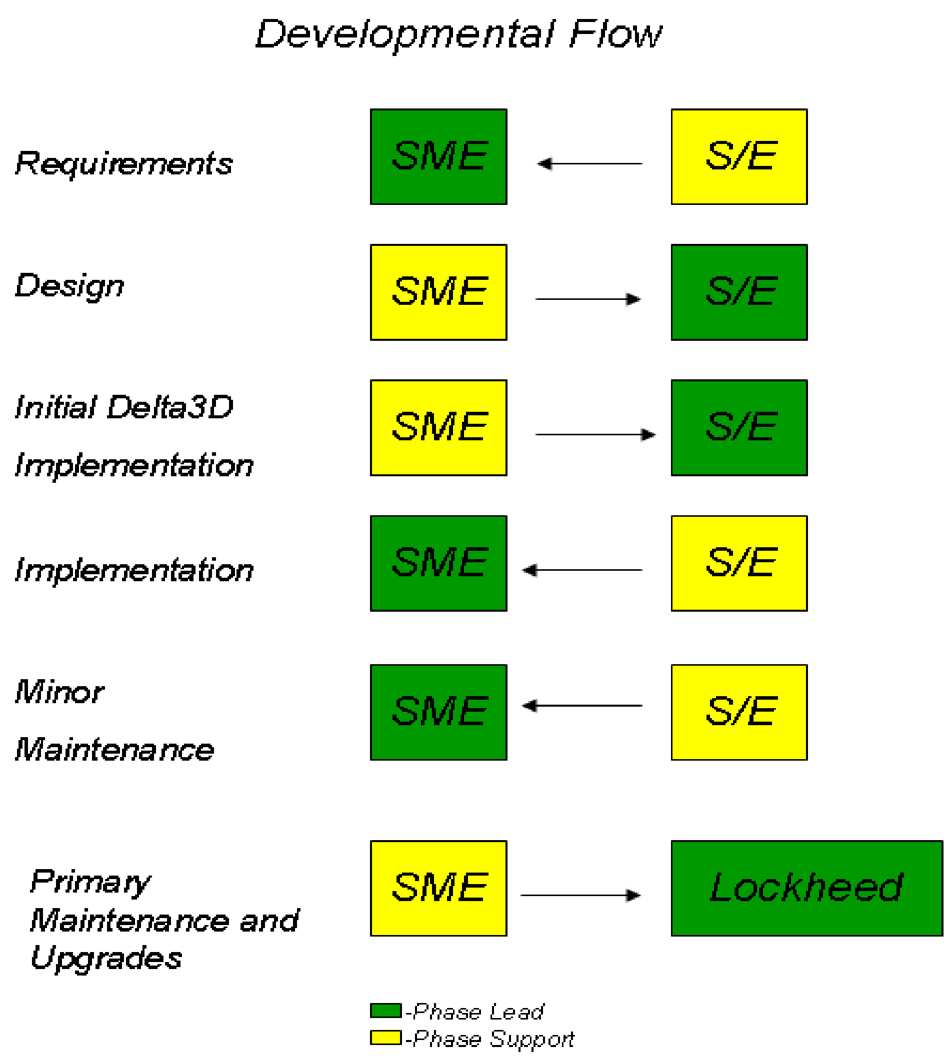


Figure 7. Developmental Flow

A. REQUIREMENTS AND DESIGN PHASE

During the Requirements and design phase we took a look at the previous system. Many of the original requirements were left untouched and were treated as a foundation for the new system. After analyzing the original requirements we began adding the

requirements that would make the new system much more user friendly primarily because we did not want users to have to rely on a trained operator or continuously referencing documentation in order to use the system. Another consideration was doing a risk assessment on requirements versus capability of open source software. If we were unable to implement our requirements with the software it would cause problem in the long run.

One of the risks first identified was with a lack of a sound system. Fortunately one of the Delta3d programmers had previous experience with sound systems in the game industry and was able to implement an audio system into the Delta3d engine. It only took him a week to implement a working system which relieved many of the fears that this could be a risk to the project.

A key component to the success of the design phase was due to the expert knowledge of Maj. McDonough., who is an Artillery Officer by profession and has even been a teacher call for fire at The Basic School in Quantico, Virginia. His direct involvement in both the design and development of the system ensured that the system performed correctly and up to the expected standard of the users. With him working full time on the project, much of the time wasted on communicating the expert knowledge to the system developers was completely eliminated.

Finally the motivation for the entire project was to provide a training tool for our fellow Marines, so the success of this system relied on its usability within the user domain. Tedious effort was put into the design of the graphical user interface (GUI) to ensure that our users would not require a skilled operator in order to train or they would not have to constantly refer to the user manual each time they used the system in order to accomplish a training objective. In order to maintain focus on the primary design, we used a basic flow chart for the call for fire to use for reference (see Figures 10 and 11, Appendix C).

B. MOVES OPEN HOUSE DEMO RELEASE

After the design was finished, the development of the system began. This phase of the development consisted of about two months with four programmers working on the project to get ready for the MOVES Open House. Not only was this going to be the

first release of FOPCSim but it was going to serve as the first release of the Delta3d engine. The MOVES Open House is a time for sponsors and the community to get together and learn about the different projects and research being conducted at the MOVES Institute. Not only were the sponsors for the Delta3d project going to attend, but representatives from the Marine Corps Technology Division were going to be present. The primary goal of this release was to showcase many of the features of the Delta3d engine using FOPCSim as the platform. This version of the system was able to complete a grid call for fire mission which enabled a user to destroy a target. During this two month phase most of the risks were eliminated and a foundation for the system was implemented. Both the sponsors and the Marine Corps were impressed giving the authors confidence that the system was on track.

C. I/ITSEC ALPHA RELEASE

After the MOVES Open House the engineers from the Delta3d project left the FOPCSim team to continue work on the engine. This phase of development consisted of about four months and culminated in a release for the I/ITSEC conference, the industry conference for DoD modeling and simulation. To get ready for this release we added two major features to the system: a networking capability through the use of the DoD High Level Architecture (HLA) and a scoring system that gave users intelligent real-time feedback based on Marine Corps standards. By using HLA for networking we could connect to other DoD simulators and C4I systems providing our system with a team training capability. By adding the scoring systems this reduced the amount of instructor interaction because students receive immediate feedback on there performance instead of relying on the instructor to provide that information. The scoring system design and grading standard is based on the Ft Sill grading standard for the Officer Basic Course graded observed fire missions (see Appendix D). In addition, this standard is completely complementary to the Marine Corps Training and Readiness Standards, MCO 3501.26A dated 11 April, 2000. By ensuring compliance with both of these standards, FOPCSim can be used by both soldiers and Marines with full confidence that they are learning the correct procedures.

During the conference we were able to view other call for fire simulators that were in developments. Of the simulators we saw, none were focused on delivering a solution down to the small unit level. What we saw were larger simulators designed to be used at a school house or base simulation center. Of note, one company was working on developing a small application that could be used during an online course of instruction.

D. TBS EXPERIMENT BETA RELEASE

After the I/ITSEC conference was over our efforts shifted to getting the simulator ready for the experiment. Our main focus shifted from adding features to system stability. It was critical that the code be as stable as possible to prevent problems with our data collection which would invalidate the experiment. We distributed copies of the CDs to the experimental group and it was important that the software would reliably run on their computers so we could gather usage data. The actual computers that we would be using for the experiment were also a mystery. We had a difficult time getting accurate technical information about the hardware of the laptops we were going to be using.

Although we put a lot of time and effort into fixing bugs and trying to discover bugs before this release, we did encounter some software crashes during the experiment. The primary cause of the crash was due to a non-null terminating string operation and a misuse of unsigned integers. This bug rarely occurred during the experiment and did not negatively affect the results.

E. FINAL NPS RELEASE

After the experiment was over our focus shifted towards fixing all the known bugs and composing the final version of the software. Immediately after the experiment we fixed the bugs that were causing the system to crash. We also upgraded the system to be compatible with the latest stable version of the Delta3D engine and removed the text to speech API that we were using and used prerecorded voice instead. Both of these changes improved the stability of the system on lower end hardware which we knew would be in the possession of the majority of our users.

Soon after version 1.0 was finalized we were contacted by the Office of Naval Research (ONR), Virtual Training and Environments (VIRTE) project, who requested use of our software for some of their experiments. They had contracted Lockheed Martin

to perform software revisions to our system in support of their experiments. Most of the changes to the system that ONR requested were to fit their experimentation needs rather than the training needs of the users, however all of the useful upgrades would be available back to the authors and the MOVES Institute for inclusion in future releases of FOPCSim. All of the results of this thesis are applicable up to the 1.0 version of the software and have not been tested with any more recent versions of the software.

VI. EXPERIMENT

A. BACKGROUND

Before accepting a virtual environment trainer (VET) as a suitable replacement or augmentation to live training, it should be evaluated for its effectiveness. Major Walt Yates, a recent graduate of the MOVES Institute at the Naval Postgraduate School (NPS), looked at this question for a marksmanship trainer that has been in use in the Marine Corps for over ten years without being evaluated. Yates states that,

> Despite how commonly VETs are used, there are many fielded VETs for which there has been no detailed study conducted to validate the effectiveness of a VET. Such studies are referred to as verification of skills acquisition (or training transfer). A positive verification of skill acquisition requires a quantified measure of improvement at task performance (Fredriksen & White, 1989). To justify the expense of developing and fielding VETs they must be verified to accomplish skill acquisition as well as conventional methods of training or a reduced level of effectiveness must be accepted as a trade-off for reduced cost or increased safety.[19]

In September 2002, Lieutenant Colonel Dave Brannon and Major Mike Villandre, students in the Computer Science Department working with the MOVES Institute at NPS, pursued the above questions concerning the task of calling for fire. They chose to develop a PC based call for fire trainer called Forward Observer PC Simulator (FOPCSim). The goal of their research was "focused on development of a virtual environment in which a trained forward observer could conduct a basic call for fire (CFF) having to execute the same procedures as he would in the real world."[20] We chose to take the idea for the application they started and continue to build on it. The major differences between version 1 and 2 are the ability to freely distribute the software without expensive runtime licenses, a more intuitive interface based on the MCRP 3-11.1A Platoon Commander's Tactical Notebook CFF worksheet, and an intelligent tutoring system.

---

19 Yates, W., *A Training Transfer Study of the Indoor Simulated Marksmanship Trainer,* Master's Thesis, Naval Postgraduate School, Monterey, California, September 2004, p. 11.

20 Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator*, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 2002, p. 2.

For their experiment, Brannon and Villandre conducted a limited study using other students at the Naval Postgraduate School. The results they obtained indicated individuals trained in the forward observer task can use FOPCSim to maintain and improve proficiency for a skill set that is perishable without regular practice.[21]

B. SETUP

For our experiment, we chose to look at students initially learning to call for fire instead of trained observers working on maintaining their proficiency. We did this at The Basic School (TBS) in Quantico, VA, where newly commissioned lieutenants receive training in the skill set needed to be platoon commanders in the Marine Corps. One of the skills they learn is how to call for and adjust indirect fire. Currently the students receive the opportunity to learn this skill through both live and virtual training. However, due to time and ammunition constraints each lieutenant gets the opportunity to do only one live mission as part of a team. This does not provide the student with enough repetition to master this task. In order to increase the number of missions that each student performs, two different types of simulation are used: "lawn darts" a physical simulation and the Training Set, Fire Observation (TSFO) a virtual simulation (see Ch. 2 for references to these simulators). "Lawn darts" are blue darts that are fired from a pneumatic insert in an actual 81mm mortar tube. This allows the setup of a miniature range where each student can call for and adjust fire while observing the mortar team operating the mortar. The TSFO was designed to permit realistic instruction to forward observers in the observation and adjustment of artillery fire and fire planning. The TSFO is an antiquated system that is based on 35mm slides and requires operator support to control the system. In order to use the system it must be scheduled in advance and have the trained operator present to run the system and troubleshoot if required. This increases the cost of each training session, which limits the amount of time students can spend training.

C. HYPOTHESIS

Our pre-test hypothesis was that students who used FOPCSim under instructor supervision for two hours and then were free to use the simulator on their personal

[21] Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator*, Master's Thesis, Naval Postgraduate School, Monterey, California, September, 2002, p. 99.

computers to practice “Calling for Fire” would complete more individual practical-application than the group which just received two hours of group instruction in the TSFO. This change would lead to better scores on the Supporting Arms Exam and better performance during the live call for fire exercise. These were the factors that we used when designing our training evaluation experiment.

D. METHOD

1. Participants

The participants were 250 predominantly male, Marine Corps Lieutenants assigned to Company B attending the Officer Basic Course, at TBS. The control group which consisted of 2/3 (166) of the company and the experimental group 1/3 (84) of the company were randomly selected based on which day of the week the participants were scheduled for training. All students were given a copy of FOPCSim: participants in the experimental group were given the simulator after their classroom training but before the final exam, and the control group did not get a copy until they completed their final exam.

2. Design and Materials

A posttest-only design was used to explore the effectiveness of a freely available, game based trainer versus a commercial, classroom-oriented, instructor-driven simulator. The independent variable was the type of simulation used: TSFO or FOPCSim. Because the participants were formally tested on the call for fire procedures, it was important that the control group and experimental group received the same level of training. The normal artillery training package consists of three phases: 2.5 hours of classroom training, 5 hours of training utilizing simulators, and a live fire artillery shoot. The normal 5 hour block of simulation training includes a 1 hour review of the call for fire procedures followed by 2 hours of TSFO simulator and 2 hours of “lawn darts” pneumatic mortar physical simulation. The experimental group received the exact same training as the control group except that the 2 hour TSFO block was replaced by 2 hours of FOPCSim training and the 1 hour review session was conducted utilizing FOPCSim vice an overhead projector. To minimize potential confounds, three separate pilot tests were conducted to identify any problems with the simulator and period of instruction.

All pilot study participants had been formally trained in call for fire procedures and provided useful information about fine tuning the simulator scenarios and instruction.

For the experimental group 15 laptops were setup up in the TSFO training building to support FOPCSim. The 1 hour review session was conducted using FOPCSim to help familiarize the students with the user interface while reviewing the basic procedures. For the two hour TSFO block, students are required to work up call for fire missions based on what they see on a large screen in the front of the classroom and one student per mission is called upon to read back the mission. The instructor critiques the call for fire as the participant conducts the mission. The benefit of this method is the whole class hears the mission and instructor's critique of that mission; they therefore have the opportunity to learn from the mistakes of others in the class. Because in a two hour session only 5-7 students have the chance to be in the "hot-seat", it is hard to identify individual students that are having problems. For the first hour of the two hour FOPCSim block, the instructor picked students to perform missions on the large screen similar to the TSFO block. For the remaining hour each student had a chance to be in the "hot-seat" and work up and input multiple missions into their own virtual environment. The simulator scored each mission and an intelligent tutor critiqued the student's performance and gave individual feedback based on the Marine Corps Training and Readiness Standards. This allowed the participants that were proficient at the call for fire procedures to complete many missions, while those participants that were having problems with the procedure could get individual help without hindering the rest of the class.

Before the simulator training was conducted a questionnaire was given to asses the level of training participants had pertaining to call for fire. After the training was given another questionnaire was given to asses how useful they thought the training was. Specifically, participants were asked to rate different characteristics of each simulator on a 5 point Likert scale. The experimental group was given a copy of the simulator software and a tracking sheet to record their usage up until the final exam. The quantifiable data came from the results of the final exam that was given on April 7th, 2005.

VII. RESULTS

The true test of how well someone can call for fire can only be evaluated by measuring their performance on a live fire mission. Unfortunately, based on time and logistical constraints the live fire missions for the students are not graded events. Instead the students each get the opportunity to conduct a live mission as part of a two person team. Until the live fire mission becomes an evaluated event, there will be no true test of the ability of students to call for fire or of the training events that prepare them for that.

Since the live fire test is not evaluated, the next best thing is the written Supporting Arms Exam that all students take. This test to evaluate their supporting arms knowledge covers several areas not specifically associated with the call for fire procedure, such as the controlling of close air support (CAS). It includes both a multiple choice portion that is computer-graded as well as a short answer/ fill in the blank portion that is hand graded by the instructors. The portions of the test that specifically covers the call for fire procedures are the multiple choice section and a portion of the hand-graded section.

Table 2 shows the comparison between the TSFO group (Group A) and the FOPCSim group on the written Supporting Arms Exam. For the statistical results we only included those students for whom we had complete scoring data and survey results. The group who used FOPCSim scored significantly higher ($p < .05$) than the TSFO group. This group was split evenly between those that did not use FOPCSim after the two hour class (Group B: 30) and those that did (Group C: 31). When looking at this data, some would argue that of course the group who got to use FOPCSim for more than two hours would do better because "more is always better." But in this case, we did not see this result.

Table 2. Supporting Arms Exam Results

	Group	N	Mean	Std. Deviation	Std. Error Mean
Overall Score	Group B & C FOPCSim	61	85.3484	10.03880	1.28534
	Group A TSFO	166	82.0959	9.96684	.77358

When we further broke up the FOPCSim group into two groups, we found that those who chose to use the simulation more did not perform statistically better than the other two groups, in fact there overall scores were lower than the group that just used it in class (see Table 3 Overall Scores). One explanation for this is those who felt comfortable with the material felt that two hours was enough, whereas, those individuals who did not, chose to use the simulation on their own. If these, indeed, corresponded to those who were less likely to do well on exam if they stopped after only 2 hours use in class, then we would get the kind of results seen for Overall Score in Table 3. Indeed, using the FOPCSim after class didn't cause low scores, but a fear of low scores caused some to use FOPCSim after class. Group C's scores might indeed be higher than if they'd taken the test after only the two hour class, but if they started from a lower base (on average) then they'd appear to do worse.

Table 3. Overall Score by Group

Subgroup		Overall
A	Mean	82.0959
TSFO	N	166
	Std. Dev.	9.96684
B	Mean	86.9111
FOPCSim	N	30
2 hrs	Std. Dev.	9.69603
C	Mean	83.8360
FOPCSim	N	31
>2 hrs	Std. Dev.	10.28932
Total	Mean	82.9699
	N	227
	Std. Dev.	10.06820

In order to further examine the data and determine the differences between the three groups we looked at the individual questions on the exam as well as the results of the scored missions for the FOPCSim group. While looking at the individual multiple choice questions we found a large difference between Group C and the rest of the subjects on one question. The reason we believe so many more subjects in Group C

missed this one question than the other groups comes from the default equipment setting for the compass in FOPCSim. If the user does not understand that the M2 compass that they used by default is calibrated to read in “mils grid” as opposed to “mils magnetic”, than they would assume that they must be sending in mils magnetic which is what the compass the subjects are issued at the Basic School use on a daily basis. In order to see if this had an effect on the data we recomputed the Overall score for all subjects without this question (Called New Overall in Table 4). When we did this we saw a much larger improvement in Group C’s scores than the other two groups (see Figure 8). In addition, we looked at the data minus those whose score was more than two standard deviations lower than the mean of their group. With this cutoff 8 of 166 were removed from Group A, 0 from Group B, and 2 from Group C. When comparing these score we see a much more significant difference ($p < .07$) between Groups A and C and very little difference amongst the entire FOPCSim group (see Table 4 New Overall (Outliers Removed).

Table 4. Adjusted Overall Score

Subgroup		Overall	New Overall	New Overall (Outliers removed)
A	Mean	82.0959	82.9794	84.3238
	N	166	166	158
	Std. Dev.	9.96684	9.49853	7.46635
B	Mean	86.9111	87.3556	87.3556
	N	30	30	30
	Std. Dev.	9.69603	8.89603	8.89603
C	Mean	83.8360	85.3414	87.0172
	N	31	31	29
	Std. Dev.	10.28932	9.51712	7.20685
Total	Mean	82.9699	83.8803	85.1029
	N	227	227	217
	Std. Dev.	10.06820	9.51529	7.71480

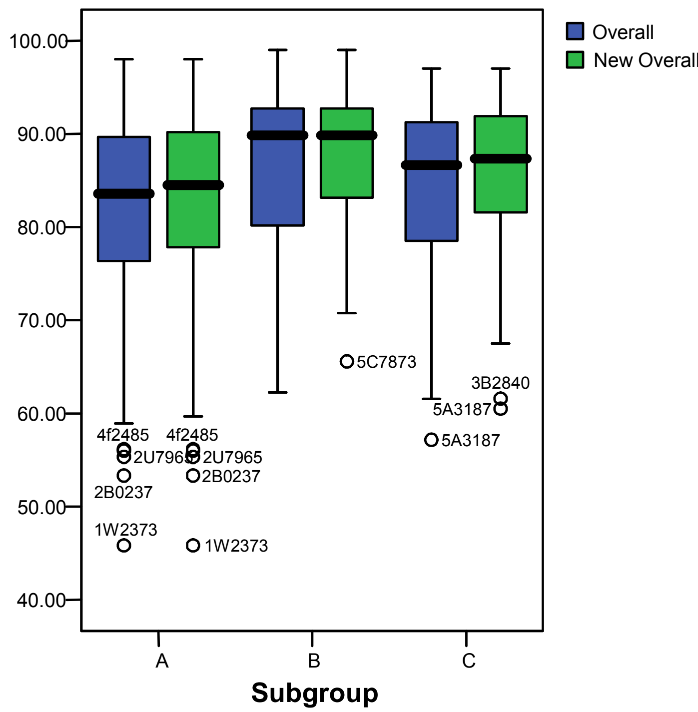


Figure 8. Adjusted Overall Scores by Subgroup

As part of the classroom training, the FOPCSim group worked individually (or as a team depending on computer availability) on four graded missions that were scored, and the results were stored as a text file on the computer. We took the results of these four missions and produced an Average SimScore for each individual or team. We then compared these scores to their results on the Supporting Arms Exam. We did not expect to get a high correlation between these Simscores ($r^2 = 0.245$) and their Supporting Arms Exam score since there were several weeks between this training session and the actual exam. However we did see that these SimScores could be used a predictor for those who would not perform as well on the Supporting Arms Exam. If we look at those who scored above an 85% on their SimScore Average, we see they are very likely to pass the Supporting Arms Exam (35 of 35). However, if we look at those who scored below an 85%, they have nearly a 20% (4 of 19) chance of failing (see Figure 9). If an instructor is given this knowledge prior to the exam he can focus his efforts on those identified by their SimScore Average to prevent them from failing the exam.

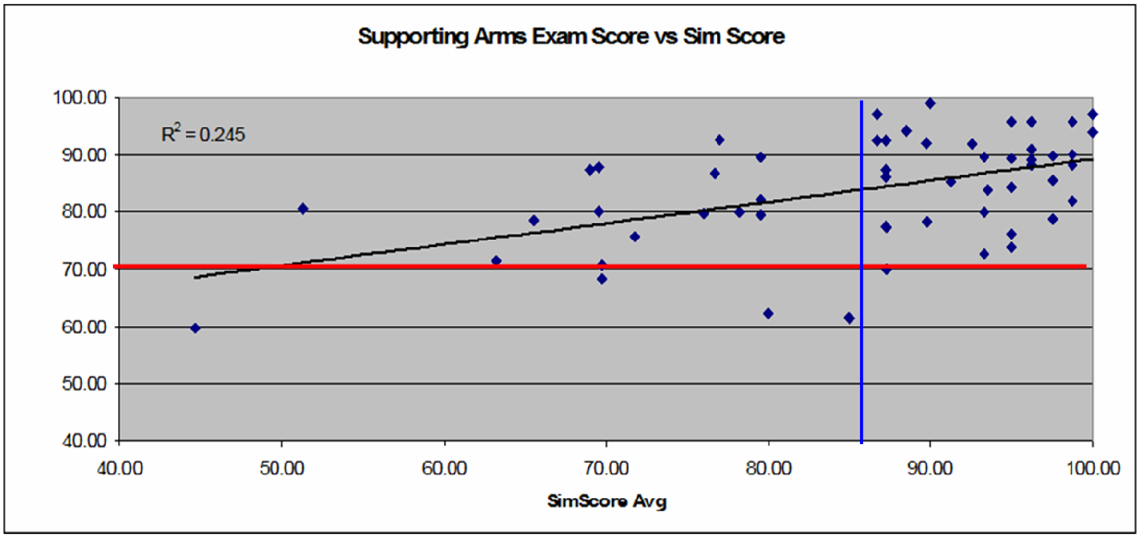


Figure 9. Supporting Arms Exam Score vs SimScore Average

A. DISCUSSION

The results of our experiment show that FOPCSim performs at least as well if not better than the existing system to train entry level students to call for and adjust indirect fire based on the results of the written Supporting Arms exam. Unfortunately, until the live fire CFF is evaluated for students at TBS, there can be no true test of how well simulation helps users learn this specific task.

The largest difference between the group that used the TSFO and the group who used FOPCSim is the number of missions that each got to perform in the virtual environment. For the TSFO group, only 5-7 of the group of twenty performed a mission in front of the group with instructor critique. In the FOPCSim group each student got the opportunity to perform several missions at their own pace during the two hour period. Since their missions were evaluated by the built in scoring system, they received feedback on each mission. In addition, if they did not understand their errors, the instructor was now free to give individuals help without interrupting the whole class.

As stated in the introduction, the amount of ammunition, time allotted, and ranges available for live fire are limited resources. Therefore, we must ensure that we make the

most out of these valuable training opportunities. In order to ensure that forward observers are not wasting time and ammunition on the "basics" of the CFF, they should be evaluated and "checked off" in the virtual environment. This concept is applicable in both a training world like TBS as well as in the operating forces. In order to determine exactly how much training is required to meet the standard further experimentation should be done.

In order to effectively employ FOPCSim, we recommend the establishment of a computer simulation lab which has a large projection screen where the instructor can demonstrate missions to the whole class as well as enough computers for each student to run their own missions. Based on survey data, some in the FOPCSim group did not have a computer with which to run the program. This hardware problem is partially due to the inability to install FOPCSim on the computers found in the TBS computer lab. These computers were not equipped with graphics cards capable of running FOPCSim (since the time of the experiment updated drivers have been released which should solve this problem).

Rarely in training is an observer given the opportunity to call for and adjust Improved Conventional Munitions (ICM) since this ammunition is normally reserved for wartime. For many observers, there first time seeing ICM fired is actual combat. What better use for a simulation than "firing" a restricted munition over and over again prior to performing a mission in the real world for the first time? There are still several areas of the CFF that are not completely incorporated into FOPCSim such as a precision registration and the adjustment of smoke screens. We believe, based on this research, that all possible forward observer tasks should be incorporated into FOPCSim. The ability to "check off" someone using simulation on one of these difficult and less frequently done tasks will improve performance and prevent the wasting of ammunition for this task.

THIS PAGE INTENTIONALLY LEFT BLANK

VIII. CONCLUSIONS

A. SUCCESS

FOPCSim was not designed to be an all-in-one simulator to train call for fire. There are several high-dollar simulators in use throughout DOD that are more technologically advanced, that cost much more to acquire and operate, and are not deployable. These systems have higher fidelity in some areas that FOPCSim does not and are excellent assets to the schoolhouses and units that can afford to acquire and maintain them. Our goal is to complement these systems with a low-cost, freely distributable, deployable system that can be used by observers to practice the call for fire when the real training is not possible. Based on the experiment we conducted, we can say that FOPCSim performs at least as well if not better than the current system used at TBS based on the testing metric used at the school.

B. LIMITATIONS

The primary limitation of FOPCSim is that it over simplifies the use of forward observer tools. CFF missions are entered via a GUI instead of a radio and aiming a compass or laser range finder can be done very precisely, unlike in the real world. Although the use of these devices is made easier in the simulation it does not impact the overall quality of training that can be conducted with FOPCSim.

Another issue that has been troublesome is compatibility with the Navy/Marine Corps Intranet (NMCI). FOPCSim was able to get around most of the installation issues with NMCI but the 3D graphics drivers on NMCI machines were not compatible with FOPCSim. Hopefully this limitation will go away in the future.

Finally, FOPCSim lacks fully featured networking capability. FOPCSim is able to tie in with other HLA systems but is unable to create scenarios that are compatible on its own. For example, two FOPCSim workstations can talk to each other but they cannot share scenarios between each other without a JSAF workstation running the scenario. Also in order for FOPCSim to connect to an AFATDS a separate gateway workstation developed by BMH Inc. must be connected to the network.

None of these limitations hinder the overall training value of FOPCSim but they point out areas of future improvements to the system. With more time most of these limitations could be overcome.

IX. FUTURE WORK

A. FOPCSIM FEATURES

Although the original design of FOPCSim 2 contained most of the options possible in the call for fire, there are some capabilities that could be added to allow observers to practice those skills beyond the basics.

1. Fire Mission Option Additions

One skill that observers are evaluated on but get very little chance to practice is the registration of an artillery battery. A registration is conducted in order to make fire from a specific unit more accurate. This procedure could be added to FOPCSim to allow observers to practice this mission which they rarely practice using live ammunition. Other additions that could be added to further train observers include the ability to conduct laser polar missions, quick smoke missions, range and/ or lateral spread illumination, coordinated illumination, and the ability to choose specific sheafs (or impact patterns). By adding the above features FOPCSim goes beyond just training the basics of call for fire to training some of the more difficult and less often practiced skills.

2. Map Tools

The ability to resize and move the map around the screen would add some ease of use to this tool. In addition the ability to use the cursor to determine distance and direction from the observer would be helpful for those users who do not have a paper map. This "Virtual Protractor" could also be used to determine the grid location of objects. However, since this tool is not normally available to the user in the real world, this must not prevent the user from becoming familiar with using a paper map and protractor to determine a grid or direction and distance. Other objects to include the firing battery's location and the location of any fire support coordination features, such as a No Fire Area (NFA), should be graphically represented on the map in accordance with the MCWP 3-16 Tactics, Techniques and Procedures for Fire Support Coordination or other applicable publications.

3. Visual after Action Review

In order to better support training during an After Action Review (AAR), a more robust capability could be added to FOPCSim, specifically for training fire support (see B 2 Quick Fire Support Plan Development Tool below). Although the current system does provide the capability to score missions and saved a text file output of the performance, a Visual AAR capability would greatly increase the ease of use of this feature. The following displays and features could be included in the AAR module:

1. "Graph paper" like display of target used to show location of each impact in relation to the target
2. Radio transmission display: Displays transmissions between the FO and FDC
3. Impact Box: Displays range and deviation distance from impact to target
4. Score Box: Comments added if errors and score updated
5. Clock: Shows updated time for each event
6. VCR Controls: Used to go forward or back to next event or >> << to start or finish

While going through a review of the mission, the transmissions and impacts would be displayed chronologically and the score updated after each shot. The controls would allow the reviewer to go through each event (transmission or impact) using the same controls found on a VCR (play, pause, fast forward, reverse, etc…).

4. Errors and Corrections

Whenever there is communication over a radio, especially under stress or fatigue there exists the chance for an error. With the call for fire, a simple slip of the tongue or reversal of numbers can lead to fratricide. Therefore it is very important to ensure that observers maintain vigilance while talking on the radio. Usually in a simulation, you can be relatively sure the computer will not make a "mistake", and so are not listening or looking for them. However by adding this probability you add a new level of realism to the simulation.

In order to handle this procedure correctly, it is imperative that the procedures to correct an error sent by the observer or by the fire direction center in FOPCSim are based on the appropriate publications: FM 6-30 Observed Fire and MCWP 3-16.6.

5. Other Nice-to-Haves

Here is a bulletized list of other features we believe would enhance the realism or ease of use of FOPCSim but did not have time to add:

- Full voice synthesizer and readback from FDC
- Flash to bang delay between visual impact and sound
- Speech recognition capability
- Spatialized sound
- Realistic “jitter” added to binos, compass and viper

B. ADD-ONS

1. GUI Mission Editor

A GUI Mission Editor used to create the XML based scenarios would be a valuable enhancement that would allow users to more easily create training scenarios. This mission editor would allow users to set the following options:

-Terrain and Map to use

-Location of Observation Posts

-Firing battery locations and call signs,

-Targets: description, location, activity, orientation

-Create Mission Order Text to include:

  -Target List Worksheet

  -Fire Support Execution Matrix

  -Scheduling worksheet

-Preplanned targets from higher’s order

-Fire Support Coordination Measures

This editor would allow the user the ability to use both a 2d map as well as look at the same terrain in the 3d virtual world in order to fine tune locations of objects.

2. Quick Fire Plan Development Tool

The GUI Mission Editor could be further enhanced to be used a Quick Fire Plan Development Tool. By adding specific capabilities to the Mission Editor tool it could be used to allow the observer to practice his skills at developing and implementing a fire support plan. Not only does a forward observer need to know how to do an on-call fire mission, he also needs to know how to plan fire support in all environments (offense, defense, patrolling, etc.).

Once a basic scenario is created by the instructor to include the mission order, applicable fire support coordination measures and other necessary planning guidance, the student will then use the Quick Fire Plan Development Tool to insert his fire support plan into the scenario prior to executing the mission in FOPCSim. The following are the list of objects that this tool would allow the user to add to the scenario:

-Observation Posts

-Pre-planned targets

-Final Protective Fires (FPF) in the defense

-Priority targets in the offense

-Additional Fire Support Coordination measures as required

Once the user has saved his Fire Plan, which is an enhanced version of the scenario provided, he would then be allowed to "fight" his plan using FOPCSim. In order to fully implement this capability some features would need to be added to FOPCSim to include: firing pre-planned missions and the capability to fire multiple missions at once. Although this capability would allow the user to practice fire support planning using FOPCSim, we believe evaluating the overall plan developed would best be done by an instructor. Although there are procedural tasks that FOPCSim can evaluate, it takes an instructor to ask, "Why did you do that?" The use of the Visual AAR tool as discussed above will greatly enhance this capability.

C. NETWORKING CAPABILITY

1. Incorporation of the Pocket-Sized Forward Entry Device (PFED)

The current networking capability allows a forward observer using FOPCSim to send a voice mission to an AFATDS operator and then observe the impacts in the virtual world. This is accomplished through the use of JSAF and a gateway between the real C4I system (AFATDS) and JSAF that was provided by BMH Inc. through the VIRTE project. In addition to being able to do a voice mission, we would also like to be able to do digital missions using the current digital entry device available to forward observers: the PFED.[22] This should not require any changes to FOPCSim; however it might require enhancements to the gateway to pass all necessary messages between the observer and the FDC. In addition, this capability should extend to whatever new digital entry devices are developed to include the Tactical Laser Designator Handoff System (TLDHS).

2. Game Style Networking

The ability to network multiple users in the same virtual environment is a mainstay of modern video games. Adding this ability to FOPCSim would allow multiple observers to train together (battalion operations). This feature has been partially implemented already in cooperation with Lockheed Martin under the VIRTE program. FOPCSim version 1.5 now allows a user to create scenarios that are then "seen" by other users in the same federation connected over HLA. If one user creates a scenario containing targets and the other users run blank scenarios with the same terrain, they will all be able to engage targets in the scenario,

[22] MARCORSYSCOM MAGTF C4ISR Ground C2 Systems, Pocket-Sized Forward Entry Device (PFED) available online http://www.marcorsyscom.usmc.mil/sites/pmgc2/pfed.asp August 2005.

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

Agg, J. Cpl, "TBS fire support training comes to life", (online) <http://www.marines.mil/marinelink/mcn2000.nsf/0/63ED1E64C546EDE785257030006396C6?opendocument> Available (August 2005).

Bailey, L. "U.S. Marine Corps chiefs call for squad-leader training", *Training & Simulation Journal*, p. 14, June/July 2005.

Brannon, M. & Villandre, D., *Forward Observer Personal Computer Simulator,* Master's Thesis, Naval Postgraduate School, Monterey, California, September 2002.

Cockayne, W. & Darken, R.P., The Application of Human Ability Requirements to Virtual Environment Interface Design and Evaluation. *Handbook of Task Analysis for Human-Computer Interaction*. Diaper, D. & Stanton, N. Eds., 2003.

Fleishman, E., & Quaintance, M., *Taxonomies of human performance: The description of human tasks*. Orlando, FL: Academic Press, 1984.

Fleishman, E. *Rating Scale Booklet, Fleishman Job Analysis Survey*, Management Research Institute Inc., 1995.

Maples, M. "Relevant and ready", *Field Artillery Journal*, pp. 1-5, November/December 2003.

MARCORSYSCOM MAGTF C4ISR Ground C2 Systems, Pocket-Sized Forward Entry Device (PFED) (online) <http://www.marcorsyscom.usmc.mil/sites/pmgc2/pfed.asp> Available (August 2005).

Mitchell, S. "Call-for-Fire Trainer and the Joint Fires Observer", *Field Artillery Journal*, pp. 11- 17, March/ April 2005.

NAVAIR, Training Systems Division, Summary of Forward Observer Training System (FOTS), January 1998, (online), <http://www.ntsc.navy.mil/Files/DEVICE_INVENTORY/Final//16C82.pdf> Available (September 2005).

Program Manager for Training Systems (PM TRASYS), Marine Corps Systems Command, Indoor Simulated Marksmanship Trainer – Enhanced (ISMT-E), (online) <http://www.marcorsyscom.usmc.mil/trasys/trasysweb.nsf/All/Indoor%20Simulated%20Marksmanship%20Trainer%20-%20Enhanced%20(ISMT-E)> Available (August 2005).

Technology Division, Training & Education Command (TECOM), Deployed Virtual Training Environment (DVTE), (online) <http://www.tecom.usmc.mil/techdiv/dvte.htm> Available (August 2005).

U.S. Army Doctrinal Publication (1991), FM 6-30 *Tactics, Techniques and Procedures for Observed Fire*, Headquarters Department of the Army, Washington, D.C.

U.S. Army Program Executive Office for Simulation, Training, & Instrumentation (PEO-STRI), Guard Unit Armory Device Full-Crew Interactive Simulation Trainer (GUARDFIST II) (online), < http://www.peostri.army.mil/PRODUCTS/FS-CATT/> Available(August 2005) .

Yates, W. *A Training Transfer Study of the Indoor Simulated Marksmanship Trainer,* Master's Thesis, Naval Postgraduate School, Monterey, California, September 2004.

APPENDIX A. COGNITIVE TASK ANALYSIS

A. FORWARD OBSERVER SIMULATOR UNIT LEVEL TASK ANALYSIS

The following task analysis was taken from the Brannon and Villandre Thesis 2002.

Goal: Desired Effects on Target: Suppress, Neutralize or Destroy.

1.0 Goal: Self-Location within 100 meters: The observer must accurately determine his position as soon as it is selected. Accurate self-location is a must for accurate target location and, thus, for effective fire with a minimum expenditure of time and ammunition. In addition to his map and compass, he should use laser range finders, position-locating systems, tank sights for resection, and so forth, whenever these devices are available.

1.1. Select:

1.1.1. Utilize GPS.

1.1.2. Utilize Map and Compass.

1.1.3. Utilize available tanks sights or laser range equipment for resection.

2.0 Goal: Fire Planning (Not part of the simulation tasks)

3.0 Goal: Choose Mission Type: Either precision fire or call for fire.

3.1. Select: Precision Fire: Precision fire procedures place a great deal of responsibility on the observer. The two types of precision missions are precision registration and destruction. In precision fire, the adjusting point must be accurately located. An eight-digit grid should be sent for precision missions unless the observer is equipped with a laser range finder, which ensures accurate target location.

3.1.1. Precision Registration Mission

3.1.2. Destruction Mission

3.2. Call for Fire: A call for fire (CFF) is a concise message prepared by the observer. It contains all information needed by the FDC to determine the method of target attack. It is a request for fire, not an order. It must be sent quickly but clearly enough that it can be understood, recorded, and read back, without error, by the FDC recorder. The observer should tell the radio operator that he has seen a target so the radio operator can start the call for fire while the target location is being determined. Information is sent, as it is

determined rather than waiting until a complete call for fire has been prepared.

3.2.1. Send-Observer Identification: Identify Observer to firing unit via the fire support net.

3.2.2. Send-Warning Order: Type of Mission, size of element to fire, method of target location.

3.2.3. Send-Target Location: Grid, polar, laser polar, shift from known point.

3.2.4. Send-Target Description: What the target is, what it is doing, number of elements, degree of protection, target shape.

3.2.5. Send-Method of Engagement: Type of adjustment, danger close, mark, trajectory, ammunition, and distribution.

3.2.6. Send-Method of Fire and Control: The method of fire and control element indicates the desired manner of attacking the target, whether the observer wants to control the time of delivery of fire, and whether he can observe the target.

3.2.7. Send-Corrections of Errors: As required.

3.2.8. Conduct-Calls for Fire from Higher Headquarters: As required.

3.2.9. Repeat-Message to Observer: Sent from firing unit.

3.2.10. Send-Additional Information: Probable error in range, angle-T, time of flight (TOF).

3.2.11. Send-Authentication: As required.

3.2.12. Conduct-Spottings: Record round's height of burst (HOB), range, and deviation did hit data.

3.2.13. Send-Corrections: Deviation, range, HOB should hit data.

3.2.14. Send-Subsequent Corrections: After the initial round(s) impact(s), the observer transmits subsequent corrections until the mission is complete.

3.2.15. Send-Refinement/ Record as Target/ end of mission (EOM)/ Surveillance

B. CALL FOR FIRE DETAILED LEVEL TASK ANALYSIS

The following detailed level task analysis was taken from the Brannon & Villandre Thesis 2002.

3.2. Select Call For Fire: A call for fire (CFF) is a concise message prepared by the observer. It contains all information needed by the FDC to determine the method of target attack. It is a request for fire, not an order. It must be sent quickly but clearly enough that it can be understood, recorded, and read back, without error, by the FDC recorder. The observer should tell the radio operator that he has seen a target so the radio operator can start the call for fire while the target location is being determined. Information is sent, as it is determined rather than waiting until a complete call for fire has been prepared. Regardless of the method of target location used, the normal call for fire is sent in three transmissions consisting of six elements as follows:

1st Transmission: Observer Identification/Warning Order

2nd transmission: Target Location

3rd Transmission: Target Description/Method of Engagement/

Method of Fire and Control.

All subsequent transmissions are for changes/corrections or to end the mission.

Send-Observer Identification/Warning Order as first transmission.

3.2.1. Observer Identification: This element of the call for fire tells the FDC who is calling for fire.

3.2.2. Warning Order: Type of Mission, size of element to fire, method of target location.

3.2.2.1. Select Type of Mission:

3.2.2.1.1. Adjust Fire: An observer's prime concern is the placement of timely and accurate fires on targets. If an observer can locate the target accurately, he will request FIRE FOR EFFECT in his call for fire. Failure to locate the target accurately may result from poor visibility, deceptive terrain, poor maps, or the observer's difficulty in pinpointing the target. If the observer cannot locate the target accurately enough to warrant FFE, he may conduct an adjustment. Even with an accurate target location, if current firing data corrections are not available, the FDO may direct that an

adjustment be conducted. Normally, one gun is used in adjustment. Special situations in which more than one gun is used are so noted in FM 6-30.

3.2.2.1.2. Fire For Effect: The purpose of area fire is to cover the target area with dense fire so that the greatest possible effects on the target can be achieved. The type and amount of ammunition requested by the observer depend on the type of target, its posture, and its activity. Fire for effect is entered during an adjust fire mission when a satisfactory adjustment has been obtained; that is, when the deviation, range, and HOB (if firing fuze time) have been corrected to provide effects on target.

3.2.2.1.3. Suppression: To quickly bring fire on a target that is not active, the observer announces SUPPRESS (followed by the target identification). Suppression (S) missions are normally fired on preplanned targets, and a duration is associated with the call for fire.

3.2.2.1.4. Immediate Suppression or Immediate Smoke: When engaging a planned target or target of opportunity that has taken friendly maneuver or aerial elements under fire, the observer announces IMMEDIATE SUPPRESSION or IMMEDIATE SMOKE (followed by the target location). Though the grid method of target location is the most common, any method of target location may be used in firing an immediate suppression or immediate smoke mission.

3.2.2.1.5. Suppression of Enemy Air Defense (SEAD): SEAD is the activity that neutralizes, destroys, or temporarily degrades enemy air defenses in a

specific area by physical attack and/ or electronic warfare.

3.2.2.2. Size of Element to Fire for Effect: The observer may request the size of the unit to fire for effect; for example, BATTALION. Usually, he does this by announcing the last letter in the battalion FDC's call sign. For example, T6H24 is announced H. The observer should never refer to a battery or other unit in the clear. He should refer to it by call sign. If the observer says nothing about the size of the element to fire, the battalion FDC makes that decision. It is based on the target attack guidance received and the graphical munitions effectiveness table (GMET) or joint munitions effectiveness manual (JMEM) solution.

3.2.2.3. Select: Method of Target Location:

3.2.2.3.1. Grid (Default): If the grid method of target location is being used, the word grid is not announced; for example, ADJUST FIRE, OVER.

3.2.2.3.2. Polar: If the target is located by the polar plot method of target location, the observer announces POLAR; for example, ADJUST FIRE, POLAR, OVER.

3.2.2.3.3. Laser Polar: The FDC needs to know as quickly as possible if the observer is using a laser. Although the data is still polar, the backup computer system (BUCS) uses a different format from the fire mission index. From the initial transmission of the call for fire, the FDC will know which of its four mission formats to display; for example, ADJUST FIRE, LASER POLAR, OVER.

3.2.2.3.4. Shift from Known Point: If the target is located by the shift from a known point method of target location, the observer announces SHIFT (followed by the known point); for example, ADJUST FIRE, SHIFT KNOWN POINT 1, OVER.

3.2.3. Send-Target Location: This element enables the FDC to plot the location of the target to determine firing data.

3.2.3.1. Grid: In a grid mission, six-place grids normally are sent. Eight-place grids should be sent for registration points or other points for which greater accuracy is required. The observer target (OT) direction normally will be sent after the entire initial call for fire, since it is not needed by the FDC to process gun-line data. For example, GRID 877540, OVER.

3.2.3.2. Polar/Laser Polar: In a polar plot mission, the word POLAR in the warning order alerts the FDC that the target will be located with respect to the observer's position. The observer's location must be known to the FDC. The observer then sends the direction and distance. A vertical shift tells the FDC how far, in meters, the target is located above or below the observer's location. Vertical shift may also be described by a vertical angle (VA), in mils, relative to the observer's location. For example, DIRECTION 2340, DISTANCE 3300, DOWN 40, OVER.

3.2.3.3. Shift from Known Point: In a shift from a known point mission, the point or target from which the shift will be made is sent in the warning order. The point must be known to both the observer and the FDC. The observer then sends the OT direction. Normally, it is sent in mils. However, the FDC can accept degrees or cardinal directions, whichever is specified by the observer. The corrections are sent next:

3.2.3.3.1. The lateral shift (how far left or right the target is) from the known point.

3.2.3.3.2. The range shift (how much farther [ADD] or closer [DROP] the target is in relation to the known point, to the nearest 100 meters).

3.2.3.3.3. The vertical shift (how much the target is above [UP] or below [DOWN] the altitude of the known point, to the nearest 5 meters). (The vertical shift is ignored unless it exceeds 30 meters.) For example: DIRECTION 4520,

LEFT 400, ADD 250, DOWN 60, OVER.

Send: Target Description/Method of Engagement/Method of Fire and Control as one transmission. This completes the initial call for fire, giving the firing unit enough information to generate gun-line data. For example, INFANTRY PLATOON DIGGING IN, ICM IN EFFECT, OVER.

3.2.4. Target Description: What the target is, what it is doing, number of elements, degree of protection, and target shape if significant.

3.2.5. Method of Engagement: The observer may indicate how he wants to attack the target. This element consists of the type of adjustment, trajectory, ammunition, and distribution. DANGER CLOSE and MARK are included as appropriate. Choose those that apply:

3.2.5.1. Type of Adjustment:

3.2.5.1.1. Precision

3.2.5.1.2. Area (Default)

3.2.5.2. Danger Close: Rounds will impact within 600 meters of friendly troops.

3.2.5.3. Mark: To orient FO in his zone of observation; to indicate target to ground troops, aircraft, or fire support.

3.2.5.4. Trajectory:

3.2.5.4.1. Low angle (Default)

3.2.5.4.2. High angle

3.2.5.5. Ammunition: The observer may request any type of ammunition during the adjustment or the FFE phase of his mission. Shell high explosive (HE) with fuze quick is normally used in adjustment. If that is what the observer desires, he need not request it in his call for fire. If the observer does not request a shell-fuze in effect, the fire direction officer (FDO) determines the shell-fuze combination. Unit standard operating procedures (SOP) may designate a standard shell-fuze combination.

3.2.5.5.1. Choose Projectile:

3.2.5.5.1.1. HE: High Explosive (Default)

3.2.5.5.1.2. WP: White Phosphorus

3.2.5.5.1.3. Illumination

3.2.5.5.1.4. IMPROVED SMOKE

3.2.5.5.1.5. FASCAM

3.2.5.5.1.5.1. ADAM

3.2.5.5.1.5.2. RAAMS

3.2.5.5.1.6. COPPERHEAD

3.2.5.5.1.7. ICM: Improved Conventional Munitions

3.2.5.5.2. Choose Fuze: Most missions are fired with fuze quick during the adjustment phase. If fuze quick is desired or if a projectile that has only one fuze is requested, fuze is not indicated. Illumination, ICM, and smoke projectiles are fuzed with time fuzes; therefore, when the observer requests ILLUMINATION, ICM, or smoke, he does not announce TIME.

3.2.5.5.2.1. QUICK (Default with HE/WP)

3.2.5.5.2.2. DELAY

3.2.5.5.2.3. TIME

3.2.5.5.2.4. VT-Variable Time

3.2.5.5.2.5. CONCRETE PIERCING

3.2.5.5.3. Choose Volume of Fire: The observer may request the number of rounds to be fired by the weapons firing in effect. For example, 3 ROUNDS indicates that the firing unit will fire three volleys.

3.2.5.6. Distribution: The observer may control the pattern of bursts in the target area. This pattern of bursts is called a sheaf. Unless otherwise requested, the battery computer system (BCS) assumes a circular target with a 100-meter radius. The BCS determines individual weapon aiming points to

distribute the bursts for best coverage of this type of target. A converged sheaf places all rounds on a specific point and is used for small, hard targets. Special sheafs of any length and width may be requested. An open sheaf separates the bursts by the maximum effective burst width of the shell fired. If target length and width are given, attitude also must be given. If target length is equal to or greater than five times the target width, the BCS assumes a linear target. The mortar ballistic computer assumes the target is linear and fires a parallel sheaf unless a special sheaf is requested.

3.2.5.6.1. Circular (Default)

3.2.5.6.2. Converged Sheaf

3.2.5.6.3. Open Sheaf

3.2.6. Method of Fire and Control: The method of fire and control element indicates the desired manner of attacking the target, whether the observer wants to control the time of delivery of fire, and whether he can observe the target.

3.2.6.1. Send-Method of Fire: In area fire, the adjustment normally is conducted with one howitzer or with the center gun of a mortar platoon or section. If for any reason the observer determines that PLATOON RIGHT (LEFT) will be more appropriate, he may request it. (Adjusting at extreme distances may be easier with two guns firing.) The normal interval of time between rounds fired by a platoon or battery right (left) is 5 seconds. If the observer wants some other interval, he may so specify.

3.2.6.2. Choose: Method of Control:

3.2.6.2.1. At my Command: If the observer wishes to control the time of delivery of fire, he includes AT MY COMMAND in the method of control. When the pieces are ready to fire, the FDC announces PLATOON (or BATTERY or BATTALION) IS READY, OVER. (Call signs are used.) The observer announces FIRE when he is ready for the pieces to fire. AT MY COMMAND remains in effect

throughout the mission until the observer announces CANCEL AT MY COMMAND, OVER.

3.2.6.2.2. Cannot Observe: Indicates that the observer cannot see the target (because of vegetation, terrain, weather, or smoke); however, he has reason to believe that a target exists at the given location and that it is important enough to justify firing on it without adjustment.

3.2.6.2.3. Time on Target: The observer may tell the FDC when he wants the rounds to impact by requesting TIME ON TARGET (so many) MINUTES FROM...NOW, OVER or TIME ON TARGET 0859, OVER. The FO must conduct a time hack to ensure that 0859 on his watch is 0859 on the FDC's watch.

3.2.6.2.4. Continuous Illumination: If no interval is given by the observer, the FDC determines the interval by the burning time of the illuminating ammunition in use. If any other interval is required, it is indicated in seconds.

3.2.6.2.5. Coordinated Illumination: The observer may order the interval between illuminating and HE shells, in seconds, to achieve a time of impact of the HE coincident with optimum illumination; or he may use normal AT MY COMMAND procedures.

3.2.6.2.6. Cease Loading: The command CEASE LOADING is used during firing of two or more rounds to indicate the suspension of loading rounds into the gun(s). The gun sections may fire any rounds that have already been loaded.

3.2.6.2.7. Check Firing: CHECK FIRING is used to cause an immediate halt in firing.

3.2.6.2.8. Continuous Fire: Continuous fire means loading and firing as rapidly as possible, consistent with accuracy, within the prescribed rate of fire for the equipment. Firing will continue until suspended by the command CEASE LOADING or CHECK FIRING.

3.2.6.2.9. Repeat: REPEAT can be given during adjustment or FFE missions. 1) During Adjustment. REPEAT means fire another round(s) with the last data and adjust for any change in ammunition if necessary. REPEAT is not sent in the initial call for fire. 2) During Fire for Effect. REPEAT means fire the same number of rounds using the same method of fire for effect as last fired. Changes in the number of guns, the previous corrections, the interval, or the ammunition may be requested.

3.2.6.2.10. Followed By: This is part of a term used to indicate a change in the rate of fire, in the type of ammunition, or in another order for fire for effect; for example, WP FOLLOWED BY HE.

3.2.7. Send-Corrections of Errors: Errors are sometimes made in transmitting data or by the FDC personnel in reading back the data. If the observer realizes that he has made an error in his transmission or that the FDC has made an error in the read back, he announces CORRECTION and transmits the correct data. When an error has been made in a sub-element and the correction of that sub-element will affect other transmitted data, CORRECTION is announced. Then the correct sub-element and all affected data are transmitted in the proper sequence.

3.2.8. Conduct-Calls for Fire from Higher Headquarters: Calls for fire from higher headquarters and from the observer are similar in format. The call for fire from higher headquarters may specify the unit to fire for effect. However, the observer's call for fire can only request the firing unit. An example of a call for fire from higher headquarters is shown below.

3.2.9. Repeat-Message to Observer: After the FDC receives the call for fire, it determines how the target will be attacked. That decision is announced to the observer in the form of a message to observer (MTO). For example, T, G, VT IN EFFECT, 4 ROUNDS**,** AA7732, OVER. The MTO consists of the four items discussed below.

3.2.9.1. Unit(s) to Fire: The battery (or batteries) that will fire the mission is (are) announced. If the battalion is firing in effect with one battery adjusting, the FDC designates the FFE unit (battalion) and the adjusting unit by using the last letter of the call sign.

3.2.9.2. Changes to the Call for Fire: Any change to what the observer requested in the call for fire is announced.

3.2.9.3. 3.Number of Rounds: The number of rounds per tube in fire for effect is announced; for example, T, G, VT IN EFFECT, 4 ROUNDS.

3.2.9.4. 3.Target Number: A target number is assigned to each mission to facilitate processing of subsequent corrections

3.2.10. Send-Additional Information: The additional information shown below normally is transmitted separately from the MTO.

3.2.10.1. Probable Error in Range (Per): If probable error in range (PEr) is 38 meters or greater during a normal mission, the FDC informs the observer. If PEr is 25 meters or greater in a precision registration, the FDC informs the observer.

3.2.10.2. Angle T: Angle T is sent to the observer when it is 500 mils or greater or when requested.

3.2.10.3. Time of Flight: Time of flight is sent to an observer during a moving target mission, during an aerial observer mission, during a high-angle mission, and for shell HE in a coordinated illumination mission when using BY SHELL AT MY COMMAND, or when requested.

3.2.11. Send-Authentication:

1) When non-secure communications are used and excluding unique fire support operations (such as suppressive fires posture), challenge and reply

authentication is considered a normal element of initial requests for indirect fire. The FDC challenges the FO after the last read back of the fire request. The FO transmits the correct authentication reply to the FDC immediately following the challenge. Authentication replies exceeding 20 seconds are automatically suspect and a basis for re-challenge. Subsequent adjustment of fire or immediate engagement of additional targets by the FO originating the initial fire request normally would not require continued challenge by the FDC. FM 24-35 provides information on authentication procedures.

2) Two methods of authentication are authorized for use: challenge and reply and transmission (which is commonly referred to as self-authentication). The operational distinction between the two is that challenge and reply requires two-way communications, whereas transmission authentication does not. Challenge and reply authentication will be used whenever possible. Transmission authentication will be used if authentication is required and it is not possible or desirable for the receiving station to reply; for example, imposed radio silence, final protective fire, and immediate suppression.

3) The FO is given a transmission authentication table as per unit standing operating procedures (SOP). The transmission authentication table consists of 40 columns of authenticators with S authenticators in each column. For immediate suppression, the FO must use the column assigned to his supporting unit. Authenticators from the numbered columns of the transmission authentication table should be used only once. The first unused authenticator in the assigned column is used, and a line is drawn through that authenticator to preclude its reuse.

3.2.12. Conduct-Spottings: A spotting is the observer's determination of the location of the burst (or the mean point of impact [MPI] of a group of bursts) with respect to the adjusting point as observed along the OT line. Spottings must be made by the observer the instant the bursts occur except when the spottings are delayed deliberately to take advantage of drifting smoke or dust. The observer is

usually required to announce his spottings during his early training; experienced observers make spottings mentally. The observer should consider the most difficult spottings first. The sequence of spottings is HOB (air or graze), range (over or short), and deviation (left or right).

3.2.12.1. Height of Burst: When fuze time is fired, the HOB is the number of mils the burst is above the target.

3.2.12.1.1. AIR: A round or group of rounds that bursts in the air. The number of mils also is given. For example, a burst 10 mils above the ground would be spotted as AIR 10.

3.2.12.1.2. GRAZE: A round or group of rounds that detonates on impact.

3.2.12.1.3. MIXED: A group of rounds that results in an equal number of airbrushes and graze bursts.

3.2.12.1.4. MIXED AIR: A group of rounds that results in both airbrushes and graze bursts when most of the bursts are airbrushes.

3.2.12.1.5. MIXED GRAZE: A group of rounds that results in both airbrushes and graze bursts when most of the bursts are graze bursts.

3.2.12.2. Range: Definite range spottings are required to make a proper range adjustment. Any range spotting other than DOUBTFUL, LOST, or UNOBSERVED is definite. Normally, a round which impacts on or near the OT line results in a definite range spotting. An observer may make a definite range spotting when the burst is not on or near the OT line by using his knowledge of the terrain, drifting smoke, shadows, and wind. However, even experienced observers must use caution and good judgment when making such spottings. Possible range spottings are as follows:

3.2.12.2.1. OVER: A round that impacts beyond the adjusting point.

3.2.12.2.2. SHORT: A round that impacts between the observer and the adjusting point.

3.2.12.2.3. TARGET: A round that impacts on the target. This spotting is used only in precision fire (registration or destruction missions).

3.2.12.2.4. RANGE CORRECT: A round that impacts at the correct range.

3.2.12.2.5. DOUBTFUL: A round that can be observed but cannot be spotted as OVER, SHORT, TARGET, or RANGE CORRECT.

3.2.12.2.6. LOST: A round whose location cannot be determined by sight or sound.

3.2.12.2.7. UNOBSERVED: A round not observed but known to have impacted (usually heard).

3.2.12.2.8. UNOBSERVED OVER or SHORT: A round not observed but known to have impacted over or short.

3.2.12.3. Deviation: A deviation spotting is the angular measurement from the adjusting point to the burst as seen from the observer's position. During a fire mission, the observer measures the deviation, in mils, with his binoculars (or another angle-measuring instrument). Deviation spottings are measured to the nearest 5 mils for area fires and 1 mil for precision fires. Deviation spottings are taken from the center of a single burst or, in the case of platoon or battery fire, from the center of the group of bursts. Deviation spottings should be made as accurately as possible to help in obtaining definite range spottings. Possible deviation spottings are as follows:

3.2.12.3.1. LINE: A round that impacts on line (LN) with the adjusting point as seen by the observer (on the OT line).

3.2.12.3.2. LEFT: A round that impacts left (L) of the adjusting point in relation to the OT line.

3.2.12.3.3. RIGHT: A round that impacts right (R) of the point in relation to the OT line.

3.2.12.4. Unobserved Spotting: At times, the observer may be able to make a spotting even though he is unable to see the round impact.

3.2.12.5. Lost Spotting: If the observer is unable to locate the round (either visually or by sound), the round is spotted LOST.

1) A round may be lost for various reasons:

a. It may be a dud (nonfunctioning fuze), resulting in no visual or audible identification.

b. The terrain may prevent the observer from spotting the round or its smoke.

c. The weather may prevent the observer from spotting the round or its smoke.

d. Enemy fire may prevent the observer from hearing or seeing the round.

e. The FO simply may have failed to spot the round.

f. Errors by the FDC or the firing piece may cause the round to be lost.

2) When dealing with a lost round, the FO must consider his own experience, the level of FDC and/or gun section training, and the location of friendly elements with respect to the target. The observer should take corrective action based on his confidence in the target location, the accuracy of fire on previous missions, whether the lost round is an initial round or a subsequent round, and the urgency of the mission.

3) When a round is lost, positive action must be taken. The observer can start a number of corrective procedures, such as one or more of the following:

a. Begin a data check throughout the system, starting with his target location data and his call for fire.

b. Request a WP round, a smoke round, or a 200-meter airburst with HE on the next round.

c. Repeat.

d. End the mission and start a new mission.

e. Make a bold shift. The observer should be very careful in making a bold distance or deviation change when the target plots in the vicinity of friendly troops.

3.2.13. Send-Corrections: After a spotting has been made, the observer must send corrections to the FDC to move the burst onto the adjusting point. The corrections are sent, in meters, in reverse of the order used in making spottings, that is, deviation, range, and HOB.

3.2.13.1. Deviation:

1) The distance in meters that the burst is to be moved (right or left) is determined by multiplying the observer's deviation spotting in mils by the OT distance in thousands of meters (the OT factor). Deviation corrections are expressed to the nearest 10 meters. A deviation correction less than 30 meters is a minor deviation correction. It should not be sent to the FDC except as refinement data or in conduct of a destruction mission.

2) To determine the OT factor when the OT range is greater than 1,000 meters, the range from the observer to the target (OT distance) is expressed to the nearest thousand and then expressed in thousands. For an OT range less than 1,000 meters, the distance is expressed to the nearest 100 meters and expressed in thousands.

3) The computed deviation correction is announced to the FDC as LEFT (or RIGHT) (so much). The correction is opposite the spotting.

4) Determination of deviation corrections is shown in Table 5-1 of FM 6-30.

5) Angle T is the angle formed by the intersection of the gun-target (GT) line and the OT line with its vertex at the target. If angle T is 500 mils or greater, the FDC should tell the observer this. If the observer is told that angle T is 500 mils or greater, at first he continues to use his OT factor to make his deviation corrections. If he sees that he is getting more of a correction than he asked for, he should consider cutting his corrections to better adjust rounds onto the target.

3.2.13.2. Range: When making a range correction, the observer attempts to "add" or "drop" the adjusting round, along the OT line, from the previous burst to the target. If his spotting was SHORT, he will add; if his spotting was OVER, he will drop. The observer must be aggressive in the adjustment phase of an adjust fire mission. He must use every opportunity to shorten that phase. He should make every effort to correct the initial round onto the target and enter FFE as soon as possible. Successive bracketing procedures should be used only when time is not critical. When conducting an adjustment onto a target, the observer may choose to establish a range bracket. Different types of range adjustments are discussed in FM 6-30.

3.2.13.3. Height of Burst:

1) One gun is used in adjusting fuze time. The observer adjusts HOB (after a 100-meter range bracket has been established by using fuze quick) to obtain a 20-meter HOB in fire for effect. He does this by announcing a correction of UP or DOWN (so many meters).

2) If the spotting of the initial round is GRAZE, an automatic correction of UP 40 is sent. If the round is an airburst, the HOB of the round (in meters) is computed (HOB spotting in mils above the adjusting point multiplied by the OT factor). The appropriate HOB correction

is given (to the nearest 5 meters) to obtain the desired 20-meter HOB.

3) Fire for effect is entered only when a correct HOB is reasonably assured. Therefore, fire for effect is never begun when either the last round observed was spotted as a graze burst or the HOB correction is greater than 40 meters. If the initial rounds in fire for effect are spotted as MIXED, the subsequent surveillance report normally includes the correction UP 20.

3.2.14. Send-Subsequent Corrections: After the initial round(s) impact(s), the observer transmits subsequent corrections until the mission is complete. If the FDC is using BCS or BUCS, all subsequent corrections or transmissions must include the target number or a means of identifying the mission to which the correction applies. These corrections include appropriate changes in elements previously transmitted and the necessary corrections for deviation, range, and HOB. Any element for which a change or correction is not desired is omitted. Elements that may require correcting and the order in which corrections are announced are as follows:

3.2.14.1. Observer-target direction: In the sequence of corrections, the OT direction is the first item sent to the FDC. It is sent if it has not been sent previously or if the OT direction changes by more than 100 mils from the previously announced direction. (Direction is normally sent to the nearest 10 mils but it can be sent to the nearest 1 mil, depending on the accuracy of the observer's equipment).

3.2.14.2. Danger close: If the adjustment of fires brings impacting rounds within danger close distance during the conduct of the mission, the observer must announce DANGER CLOSE to the FDC. The observer, using creeping fire (paragraph 5-6d), makes corrections from the round impacting closest to friendly troops. If the adjustment of fire moves the round outside the danger close distance, the observer transmits CANCEL DANGER CLOSE. Danger close distance for Artillery or mortars is 600 meters.

3.2.14.3. Trajectory: The observer requests a change in the type of trajectory if it becomes apparent that high-angle fire is necessary during a low-angle adjustment or that high angle fire is no longer necessary during a high-angle adjustment. For example, if during the conduct of the mission a target moves into a defilade position, the observer may change trajectory by transmitting the correction HIGH ANGLE. Conversely, if a target moves out of defilade into open terrain and high-angle fire is no longer necessary, the observer requests CANCEL HIGH ANGLE.

3.2.14.4. Method of Fire: The observer transmits any correction he wants to make in the method of fire. For example, if the observer wants to change from one gun to a platoon firing in order from left to right, he transmits the correction PLATOON LEFT. If he wants to change to a platoon firing in order from right to left, he transmits the correction PLATOON RIGHT.

3.2.14.5. Distribution: If an observer wants to change the distribution of fire from a BCS sheaf (circular with a 100meter radius) to another type of sheaf, he transmits the sheaf desired (for example, CONVERGE, OPEN, or LINEAR or the target length, width, and attitude). Conversely, if the observer wants to change from a specific sheaf to a BCS sheaf, he transmits the Correction CANCEL, followed by the type of sheaf being used (for example, CANCEL CONVERGE [or OPEN] SHEAF).

3.2.14.6. Projectile: If the observer wants to change the type of projectile, he announces the desired change (for example, SMOKE or WP).

3.2.14.7. Fuze: If the observer wants to change the type of fuze or fuze action, he announces the desired change (for example, TIME, DELAY, or VT).

3.2.14.8. Volume: If the observer wants to change the volume of fire, he announces the desired change (for example, 2 ROUNDS or 3 ROUNDS). Volume refers to the number of rounds in the fire-for-effect phase.

3.2.14.9. Deviation correction: If the round impacts to the right or left of the OT line, the observer determines the correction required, to the nearest 10 meters, to bring the round onto the OT line. To make the correction, the observer transmits RIGHT (or LEFT)(so many meters). (Deviation corrections less than 30 meters are not sent to the FDC except when conducting a destruction mission or as refinement data).

3.2.14.10. Range correction: If the round impacts beyond the target on the OT line, the observer's correction is DROP (so many meters). If the round impacts between the observer and the target, the range correction is ADD (so many meters).

3.2.14.11. Height-of-burst correction: The observer transmits HOB corrections to the nearest 5 meters with the correction UP (or DOWN). In firing fuze time in an area mission, HOB corrections are made after the deviation and range have been corrected to within 50 meters of the target by using fuze quick in adjustment.

3.2.14.12. Target Description: Target description is sent before a control correction during immediate suppression missions and when a new target is being attacked without sending a new call for fire.

3.2.14.13. Mission type and/or method of control: If the observer wants to change the mission type and/or method of control, he transmits the desired method of control (for example, ADJUST FIRE, FIRE FOR EFFECT, or AT MY COMMAND). If the method of control being used includes AT MY COMMAND, his correction is CANCEL AT MY COMMAND.

3.2.14.14. Splash: An observer in a tactical situation may have difficulty identifying or observing his rounds. This may be because he has to stay down in a concealed position much of the time or because of other fire missions being conducted in the area. In any case, he may request assistance from the FDC by requesting SPLASH. The FDC informs the observer that

his round is about to impact by announcing SPLASH 5 seconds before the round impacts. The observer may end splash by announcing CANCEL SPLASH.

3.2.14.15. Repeat: REPEAT is used (in the adjustment phase) if the observer wants a subsequent round or group of rounds fired with no corrections to deviation, range, or HOB (for example, TIME, REPEAT). REPEAT is also used by the observer to indicate that he wants fire for effect repeated with or without changes or corrections to any of the elements (for example, ADD 50, REPEAT).

3.2.15. Send-Refinement/Record as Target/End of Mission/Surveillance: The observer should observe the results of the fire for effect and then take whatever action is necessary to complete the mission. Table 1 shows the observer's actions and example transmissions after the FFE rounds have been observed.

3.2.15.1. Refinement

3.2.15.2. Record as Target

3.2.15.3. End of Mission

3.2.15.4. Surveillance

Results of FFE	**Observer's Actions**	**Observer's Transmission**
Accurate and sufficient	End of mission	"END OF MISSION, RPG SUPPRESSED, OVER"
Accurate and sufficient; re-plot grid desired	Request re-plot grid; end of mission; send surveillance	"RECORD AS TARGET, END OF MISSION, BMP NUETRALIZED, OVER"
Inaccurate and sufficient	Refinement; end of mission; send surveillance	"RIGHT 20, ADD 10, END OF MISSION, RPG SILENCED"

Inaccurate, sufficient, target re-plot grid desired	Correction; request re-plot grid; end of mission; send surveillance	“RIGHT 10, RECORD AS TARGET, END OF MISSION, BMP NEUTRALIZED, OVER"
Inaccurate and insufficient	Refinement and repeat or re-enter adjust fire	"RIGHT 10, ADD 50, REPEAT" or "RIGHT 10, ADD 100, ADJUST FIRE, OVER"
Accurate and insufficient	Repeat	"REPEAT, OVER"

Table 5. Example Transmissions after FFE rounds observed

C. FOPCSIM MAPPING ANALYSIS

Call for Fire Task Analysis

Goal: Desired Effects on Target: Suppress, Neutralize or Destroy.

1.0 Goal: Self-Location within 100 meters:

1.1 Select:

1.1.1 Utilize GPS.

1.1.2 Utilize Map and Compass.

1.1.3 Utilize available tanks sights or laser range equipment for resection.

2.0 Goal: Fire Planning (Not part of the simulation tasks)

3.0 Goal: Choose Mission Type: Either precision fire or call for fire.

3.1 Select: Precision Fire

3.1.1 Precision Registration Mission

3.1.2 Destruction Mission

3.2 Call for Fire

3.2.1 Send-Observer Identification

3.2.2 Send-Warning Order:

3.2.2.1 Select Type of Mission

3.2.2.1.1 Adjust Fire

3.2.2.1.2 Fire for Effect

3.2.2.1.3 Suppression

3.2.2.1.4 Immediate Suppression or Smoke

3.2.2.1.5 Suppression of Enemy Air Defense (SEAD)

3.2.2.2 Size of element to Fire for Effect

3.2.2.3 Select Method of Target Location

3.2.2.3.1 Grid

3.2.2.3.2 Polar

3.2.2.3.3 Laser Polar

3.2.2.3.4 Shift from Known Point:

3.2.3 Send-Target Location

3.2.3.1 Grid

3.2.3.2 Polar/Laser Polar

3.2.3.3 Shift from Known Point:

3.2.4 Send-Target Description

3.2.5 Send-Method of Engagement

3.2.5.1 Type of Adjustment

3.2.5.2 Danger Close

3.2.5.3 Mark

3.2.5.4 Trajectory

3.2.5.5 Ammunition

3.2.5.5.1 Choose Projectile

3.2.5.5.1.1 HE High Explosive (default)

3.2.5.5.1.2 WP: White Phosphurus

3.2.5.5.1.3 Illuminstion

3.2.5.5.1.4 M825 Improved Smoke

3.2.5.5.1.5 FASCAM

3.2.5.5.1.5.1 ADAM

3.2.5.5.1.5.2 RAAMS

3.2.5.5.1.6 CopperHead

3.2.5.5.1.7 ICM Improved Conventional Munition

3.2.5.5.2 Choose Fuse

3.2.5.5.2.1 QUICK (Default with HE and WP)

3.2.5.5.2.2 DELAY

3.2.5.5.2.3 TIME

3.2.5.5.2.4 VT Variable Time

3.2.5.5.2.5 CONCRETE PEIRCING

3.2.5.5.3 Choose Volume of Fire

3.2.5.6 Distribution
3.2.6 Send-Method of Fire and Control:.
3.2.6.1 Send Method of Fire
3.2.6.2 Choose Method of Control
3.2.6.2.1 At My Command
3.2.6.2.2 Cannot Observe
3.2.6.2.3 Time on Target
3.2.6.2.4 Continuous Illumination
3.2.6.2.5 Coordinated Illumination
3.2.6.2.6 Cease Loading
3.2.6.2.7 Check Firing
3.2.6.2.8 Continuous Fire
3.2.6.2.9 Repeat
3.2.6.2.10 Followed by:
3.2.7 Send Corrections of Transmission Errors: As required.
3.2.8 Conduct-Calls for Fire from Higher Headquarters: As required.
3.2.9 Repeat-Message to Observer: Sent from firing unit.
3.2.10 Send-Additional Information
3.2.11 Send-Authentication: As required.
3.2.12 Conduct-Spottings:
3.2.12.1 Height of Burst
3.2.12.2 Range
3.2.12.3 Deviation
3.2.13 Send-Corrections: .
3.2.13.1 Deviation:
3.2.13.2 Range
3.2.13.3 Height of Burst:
3.2.14 Send-Subsequent Corrections:
3.2.14.1 Observer Target Direction
3.2.14.2 Danger Close
3.2.14.3 Trajectory
3.2.14.4 Method of Fire
3.2.14.5 Distribution
3.2.14.6 Projectile
3.2.14.7 Fuse
3.2.14.8 Volume
3.2.14.9 Deviation Correction
3.2.14.10 Range Correction
3.2.14.11 Height of Burst Correction
3.2.14.12 Target Description
3.2.14.13 Mission type and/or methof of control
3.2.14.14 Splash
3.2.14.15 Repeat
3.2.15 Send End of Mission Statement
3.2.15.1 Refinement
3.2.15.2 Record as target
3.2.15.3 End of Mission
3.2.15.4 Surveillance

LEGEND

Not Modeled in FOPCSim
Modeled in FOPCSim

Table 6. Mapping of real world task to FOPCSim

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX B. HUMAN ABILITIES REQUIREMENTS ASSESSMENT

Call For Fire Human Abilities Requirements Assessment — Absence/ Presence Test

Actual CFF

TASK	oral comprehension	oral expression	memorization	problem sensitivity	mathematical reasoning	Number Facility	Deductive reasoning	Information Ordering	Spatial Orientation	Visualization	Perceptual Speed	Time Sharing	Control Precision	Reaction Time	Arm Hand Steadiness	Near Vision	Far Vision	Night Vision	Depth Perception	Glare Sensitivity	Hearing Sensitivity	Auditory Attention	Sound Localization	Speech Recognition	Speech Clarity	Map Reading	Electronic Knowledge
Goal: Desired Effects on Target: Suppress, Neutralize or Destroy.																											
1.0 Goal: Self-Location within 100 meters:																											
1.1 Select:							1																				
1.1.1 Utilize GPS.						1			1	1			1		1	1										1	1
1.1.2 Utilize Map and Compass.					1	1			1	1		1			1	1	1		1	1						1	
1.1.3 Utilize available tanks sights or laser range equipment for resection.					1	1			1	1			1		1	1	1		1	1						1	1
2.0 Goal: Fire Planning (Not part of the simulation tasks)																											
3.0 Goal: Choose Mission Type: Either precision fire or call for fire.																											
3.1 Select: Precision Fire					1	1	1	1		1				1		1	1										
3.1.1 Precision Registration Mission	1	1			1			1	1	1				1	1		1		1	1							
3.1.2 Destruction Mission	1	1			1			1	1	1				1			1		1	1							
3.2 Call for Fire																											
3.2.1 Send-Observer Identification	1	1						1																1	1		
3.2.2 Send-Warning Order:	1	1					1	1											1					1	1		
3.2.3 Send-Target Location	1	1			1			1									1		1	1				1	1	1	1
3.2.3.1 Grid						1			1							1	1	1	1	1						1	
3.2.3.2 Polar/Laser Polar						1		1	1	1					1	1	1	1	1	1						1	
3.2.3.3 Shift from Known Point:						1		1	1	1					1	1	1	1	1	1						1	
3.2.4 Send-Target Description	1	1						1		1	1						1		1	1				1	1		
3.2.5 Send-Method of Engagement	1	1					1	1																1	1		
3.2.6 Send-Method of Fire and Control:.	1	1						1		1	1	1	1											1	1		
3.2.7 Send-Corrections of Transmission Errors: As required.	1	1		1		1		1																1	1		
3.2.8 Conduct-Calls for Fire from Higher Headquarters: As required.	SAME PROCESS AS CALL FOR FIRE																										
3.2.9 Repeat-Message to Observer: Sent from firing unit.	1	1	1					1																1	1		
3.2.10 Send-Additional Information	1	1						1																1	1		
3.2.11 Send-Authentication: As required.	1	1																									
3.2.12 Conduct-Spottings:			1						1	1		1		1	1		1	1	1	1	1	1	1				
3.2.12.1 Height of Burst									1	1				1	1	1	1	1	1	1	1	1	1				
3.2.12.2 Range					1	1			1	1				1	1		1	1	1	1							
3.2.12.3 Deviation					1	1			1	1				1	1	1	1	1	1	1							
3.2.13 Send-Corrections: .	1	1				1		1																1	1		
3.2.13.1 Deviation:					1																			1	1		
3.2.13.2 Range																								1	1		
3.2.13.3 Height of Burst:																								1	1		
3.2.14 Send-Subsequent Corrections:	1	1	1					1																1	1		
3.2.15 Send-Refinement/ Record as Target/ end of mission (EOM)/ Surveillance	1	1						1																1	1		

Ability type

Ability type	
Cognitive	Not Modeled in Simulation
Pyschomoter	Overall Task
Sensory/ Perceptual	Complete process
Knowledge Skills Scales	

Table 7. Human Ability Requirements Assessment: Live CFF

Call For Fire Human Abilities Requirements Assessment | Absence/ Presence Test

FOPCSIM

Task	oral comprehension	oral expression	memorization	problem sensitivity	mathematical reasoning	Number Facility	Deductive reasoning	Information Ordering	Spatial Orientation	Visualization	Perceptual Speed	Time Sharing	Control Precision	Reaction Time	Arm Hand Steadiness	Near Vision	Far Vision	Night Vision	Depth Perception	Glare Sensitivity	Hearing Sensitivity	Auditory Attention	Sound Localization	Speech Recognition	Speech Clarity	Map Reading	Electronic Knowledge
Goal: Desired Effects on Target: Suppress, Neutralize or Destroy.																											
1.0 Goal: Self-Location within 100 meters:																											
1.1 Select:							1																				
1.1.1 Utilize GPS.						1			1	1						1										1	
1.1.2 Utilize Map and Compass.					1	1			1	1		1				1										1	
1.1.3 Utilize available tanks sights or laser range equipment for resection.					1	1			1	1			1		1	1										1	
2.0 Goal: Fire Planning																											
3.0 Goal: Choose Mission Type: Either precision fire or call for fire																											
3.1 Select: Precision Fire																											
3.1.1 Precision Registration Mission																											
3.1.2 Destruction Mission																											
3.2 Call for Fire																											
3.2.1 Send-Observer Identification								1																			
3.2.2 Send-Warning Order:							1	1								1											
3.2.3 Send-Target Location					1			1								1										1	1
3.2.3.1 Grid						1			1							1										1	
3.2.3.2 Polar/Laser Polar						1		1	1	1						1										1	
3.2.3.3 Shift from Known Point:						1		1	1	1						1				1						1	
3.2.4 Send-Target Description								1		1	1					1											
3.2.5 Send-Method of Engagement							1	1																			
3.2.6 Send-Method of Fire and Control:.								1		1	1	1	1														
3.2.7 Send-Corrections of Errors: As required.	1			1		1		1																1			
3.2.8 Conduct-Calls for Fire from Higher Headquarters: As required.	SAME PROCESS AS CALL FOR FIRE																										
3.2.9 Repeat-Message to Observer: Sent from firing unit.			1					1																			
3.2.10 Send-Additional Information								1																			
3.2.11 Send-Authentication: As required.																											
3.2.12 Conduct-Spottings:			1						1	1		1		1		1											
3.2.12.1 Height of Burst									1	1				1		1											
3.2.12.2 Range					1	1			1	1				1		1											
3.2.12.3 Deviation					1	1			1	1				1		1											
3.2.13 Send-Corrections: .						1		1																			
3.2.13.1 Deviation:					1																						
3.2.13.2 Range																											
3.2.13.3 Height of Burst:																											
3.2.14 Send-Subsequent Corrections:			1					1																			
3.2.15 Send-Refinement/ Record as Target/ end of mission (EOM)/ Surveillance								1																			

Ability type	
Cognitive	Not Modeled in Simulation
Pyschomoter	Overall Task
Sensory/ Perceptual	Complete process
Knowledge Skills Scales	

Table 8. Human Abilities Requirements Assessment: Simulation

Call For Fire Human Abilities Requirements Assessment Comparison — Absence/ Presence Test

Task	oral comprehension	oral expression	memorization	problem sensitivity	mathematical reasoning	Number Facility	Deductive reasoning	Information Ordering	Spatial Orientation	Visualization	Perceptual Speed	Time Sharing	Control Precision	Reaction Time	Arm Hand Steadiness	Near Vision	Far Vision	Night Vision	Depth Perception	Glare Sensitivity	Hearing Sensitivity	Auditory Attention	Sound Localization	Speech Recognition	Speech Clarity	Map Reading	Electronic Knowledge
Goal: Desired Effects on Target: Suppress, Neutralize or Destroy.																											
1.0 Goal: Self-Location within 100 meters:																											
1.1 Select:							M																				
1.1.1 Utilize GPS.						M			M	M			X		X	M										M	X
1.1.2 Utilize Map and Compass.					M	M			M	M		M			X	M	X		X	X						M	
1.1.3 Utilize available tanks sights or laser range equipment for resection.					M	M			M	M			M		M	M	X		X	X						M	X
2.0 Goal: Fire Planning (Not part of the simulation tasks)																											
3.0 Goal: Choose Mission Type: Either precision fire or call for fire.																											
3.1 Select: Precision Fire																											
3.1.1 Precision Registration Mission																											
3.1.2 Destruction Mission																											
3.2 Call for Fire																											
3.2.1 Send-Observer Identification	X	X						M																X	X		
3.2.2 Send-Warning Order:	X	X					M	M								*			X					X	X		
3.2.3 Send-Target Location	X	X			M			M								*	X		X	X				X	X	M	M
3.2.3.1 Grid						M			M							M	X	X	X	X						M	
3.2.3.2 Polar/Laser Polar						M		M	M	M					X	M	X	X	X	X						M	
3.2.3.3 Shift from Known Point:						M		M	M	M					X	M	X	X	X	M						M	
3.2.4 Send-Target Description	X	X						M		M	M					*	X		X	X				X	X		
3.2.5 Send-Method of Engagement	X	X					M	M																X	X		
3.2.6 Send-Method of Fire and Control:.	X	X						M		M	M	M	M											X	X		
3.2.7 Send-Corrections of Errors: As required.	M	X		M		M		M																M	X		
3.2.8 Conduct-Calls for Fire from Higher Headquarters: As required.	SAME PROCESS AS CALL FOR FIRE																										
3.2.9 Repeat-Message to Observer: Sent from firing unit.	X	X	M					M																X	X		
3.2.10 Send-Additional Information	X	X						M																X	X		
3.2.11 Send-Authentication: As required.																											
3.2.12 Conduct-Spottings:			M						M	M		M		M	X	*	X	X	X	X	X	X	X				
3.2.12.1 Height of Burst									M	M				M	X	M	X	X	X	X	X	X	X				
3.2.12.2 Range					M	M			M	M				M	X	*	X	X	X	X							
3.2.12.3 Deviation					M	M			M	M				M	X	M	X	X	X	X							
3.2.13 Send-Corrections: .	X	X				M		M																X	X		
3.2.13.1 Deviation:					M																			X	X		
3.2.13.2 Range																								X	X		
3.2.13.3 Height of Burst:																											
3.2.14 Send-Subsequent Corrections:	X	X	M					M																X	X		
3.2.15 Send-Refinement/ Record as Target/ end of mission (EOM)/ Surveillance	X	X						M																X	X		

Ability type

- Cognitive
- Pyschomoter
- Sensory/ Perceptual
- Knowledge Skills Scales

- Not Modeled in Simulation
- Overall Task
- Complete process

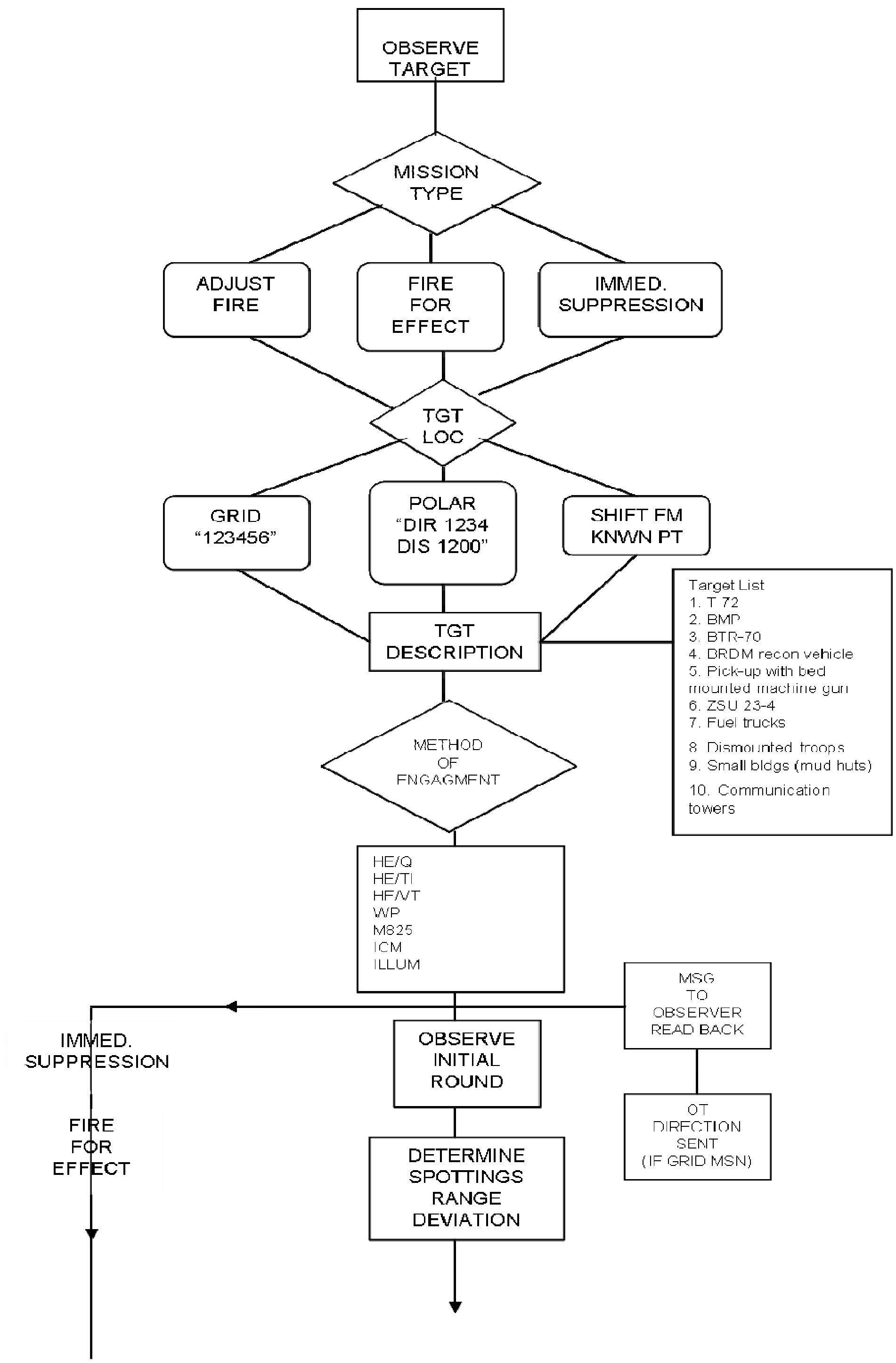
- X Skill Used in Real World but not in Simulation
- * Skill Used in Simulation but not in Real World
- M Skill Used in both Real World and Simulation

Table 9. Human Abilities Requirements Comparison

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C. DESIGN DOCUMENTS

A. CALL FOR FIRE FLOW CHART



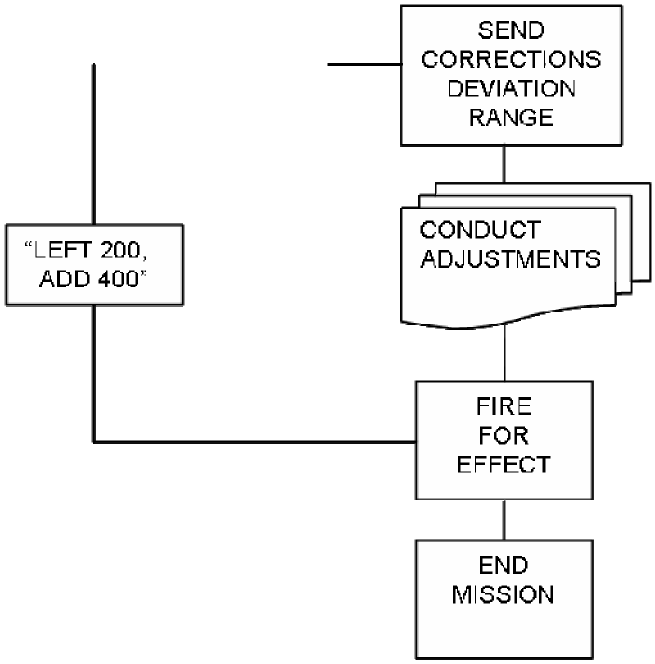


Figure 10. Call for Fire Flowchart

B. SYSTEM ARCHITECTURE

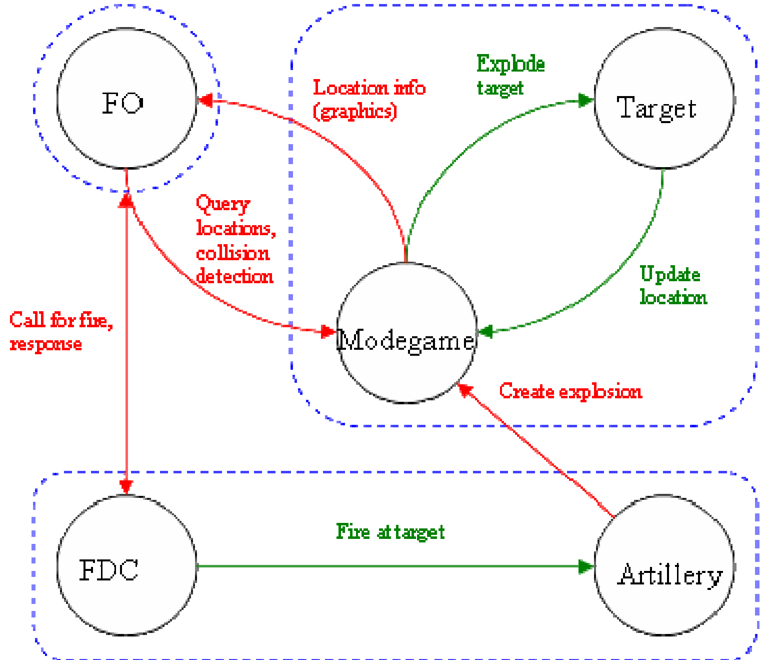


Figure 11. FOPCSim 2 System Architecture

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX D. FORT SILL GRADING STANDARD

1. General.

a. Instructors must insure that grading is consistent from mission to mission, and that every student has an equal opportunity to complete his mission.

b. Each mission is graded on its own merits. The instructor must place himself in the position of the student, and after making allowances for the advantages he has over the student (target area knowledge), he must decide whether he could do better on each round. This decision is made at the same time that the student takes the action that is being judged and before subsequent rounds prove or disprove the validity of the student's action. For example, the instructor must decide at the same time a correction is made whether it is a proper correction, not after a subsequent round proves the correction is correct or incorrect. The instructor must be sure **in his own mind** what the proper spotting is; he should not rely on a poll of the class to fortify his own spotting or to assure himself that the student's spotting is incorrect. The instructor must decide when he hears the student's call for fire whether an element of the call is correct or incorrect. To assess a cut for a wasted round, the instructor must **predict** that the student will waste a round immediately after he hears the student's correction and before he sees the next round.

Note: If an instructor has any doubt on the spotting of a student's round rather than penalize the student points on their shoot score, give students the benefit of the doubt.

2. Grading Cards.

a. General. Instructors complete a Shoot Grading Card (FS Form 87-1) for each student who fires, and prepares the administration portion of these cards in advance. All instructors have sufficient blank FS 87-1s to meet contingencies. Each instructor maintains their students' shoot grade card on file until the student graduates.

b. Filling out the Grade Card. The instructor, using abbreviations, records the call for fire, his own spotting, the students subsequent corrections, and problems. Each student error is circled and the appropriate cut entered in the CUT column. The remarks

space is used to explain the reason for the cuts. Target location error is determined and appropriate cuts are applied. All cuts are then totaled and subtracted from the maximum possible score, and the final score is recorded.

c. Target Location Error (TLE). There are two methods that an instructor may use to determine a students target location error: total range and deviation corrections or instructor spotting.

(1) Total range and deviation corrections. If the guns are firing accurately, the student's range and deviation corrections are summed to determine the TLE.

EXAMPLE: R100, +400; R40, -200; L30, +100; +50 FFE =

Total correction of R120, +350

(2) Instructor Spotting. If the Guns are firing erratically, then the instructor must subjectively spot the student's initial round and compute TLE.

3. Procedural Errors (PE).

a. Minor procedural errors. A cut of 1 point is assessed for each minor procedural error that is not corrected by the student on his own initiative.

b. Procedural errors. A cut of 5 points is assessed for each procedural error that is not corrected by the student on his own initiative. Procedural errors consist of the data being sent in an untimely manner or omitted, sent in the wrong sequence, or sent to the wrong accuracy.

c. Major procedural error. A cut of 10 points is assessed for each major procedural error that is not corrected by the student on his own initiative.

4. Refusing to Fire. When a student is called on he is expected to fire the mission. If the student makes no attempt to send data to the FDC (other than to send the first transmission) within 45 seconds of being called on, the instructor will require the student to state whether or not he intends to send data. If his reply is negative, he is given a grade of zero.

5. Performance Goals.

a. The student must enter FFE using no more than five adjusting rounds (this does not include the initial round).

b. The FFE must have effects on target (impact or burst within 50 meters of the target).

c. The student must formulate and transmit their call for fire within 120 seconds or less.

6. Grading Standards.

a. The student must meet all performance objectives and maintain a score of 70 or above to satisfactorily pass the mission.

b. Each student is allowed five adjusting rounds.

c. If the student fails to achieve all performance goals, the maximum grade awarded is 69, or 100 minus the total number of cuts, whichever is less.

d. The maximum number of cuts prior to the first round impacting is 20 points.

e. When it becomes apparent that a student is floundering, the instructor will offer instructor help. The instructor can only offer instructor help a maximum of three times. Then the mission is terminated and the maximum grade to be awarded is 69 minus the total number of cuts.

7. Threat Vehicle Identification

a. Threat identification consists of two parts vehicle identification and vehicle knowledge.

b. Maximum number of points awarded for the threat vehicle identification is five points. If a student identifies the threat vehicle picture correctly in the third transmission of the initial call for fire then the student is asked a knowledge question. If the student correctly identifies the vehicle and correctly answers the threat vehicle question they lose no points. However, if the student fails to correctly identify the threat vehicle they lose five points from their shoot score. If the student correctly identifies the vehicle and incorrectly answers the threat knowledge question the student is penalized two and a half points from their shoot score.

c. The threat knowledge question consists of a question based upon the capability of the threat vehicle shown for identification.

8. Mission Time Requirements

a. All three transmissions of the call for fire must be completed within 45 seconds after the mission is initiated in order to not lose points against their shoot score. A student has a total of 120 seconds to complete the entire call for fire or receive 69 points for failing a performance goal.

9. Cut Sheet.

a. Target Location Error Deductions.

(0M to 250M) = -0

(251M to 400M) = -5

(401M to 550M) = -10

(> 551M) = -15

b. After 45 seconds the students will lose points based on the following time brackets:

(0 to 45 seconds) = 0

(46 sec to 60 sec) = -5

(61 sec to 90 sec) = -10

(91 sec to 120 sec) = -15

(120 or more)= highest grade possible 69

c. Minor Procedural Error (-1).

(1) Improper readback.

(2) Wrong callsign.

(3) Failure to say, or incorrect use of, "over/out."

(4) Student says number/ letter incorrectly.

(5) Improper Refinements/Surveillance during EOM.

(6) Student says "Target description" in CFF.

(7) Student says "target" neutralized instead of actual target description in RREMS data.

d. Procedural Error (-5).

(1) Sequence, omission or format error.

(2) Wrong or no target description or sh/fz requested.

(3) No direction sent.

(4) No refinement, EOM, or surveillance.

(5) Incorrect sequence of subsequent corrections.

(6) Direction error greater than 100 mils.

(7) Deviation correction of less than 30 meters.

(8) Deviation correction sent to the nearest meter.

(9) Fail to correct/ minor correction errors.

(10) Fail to correct range during subsequent adjustments (Obvious + or -).

(11) Creeping fires (three or more subsequent adjustment in the same direction which either fail to establish a bracket, or have effects on target), except during danger close missions.

(12) Incorrect application of OT factor.

(13) Failure to request/cancel Danger Close or Cancel Danger Close

(14) Wrong vehicle identification, subtract 2.5 points for incorrect answer to vehicle question.

d. Major PE (ALL-10).

(1) Wrong adjusting point.

(2) Student loses visible round.

(3) Correction wrong way during subsequent adjustments (Dev or Rg).

(4) Wasted round (includes 2 rounds fired at the same range).

(5) Instructor help.

Note: If a student fails to have effects within 50 meters of the target or complete the entire call for fire within 120 seconds, he can receive no higher than a 69 on his fire mission. He may score lower based on the cumulative deductions for his mission

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Marine Corps Representative
   Naval Postgraduate School
   Monterey, California

4. Director, Training and Education, MCCDC, Code C46
   Quantico, Virginia

5. Director, Marine Corps Research Center, MCCDC, Code C40RC
   Quantico, Virginia

6. Marine Corps Tactical Systems Support Activity (Attn: Operations Officer)
   Camp Pendleton, California